



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 4 MISSION REPORT

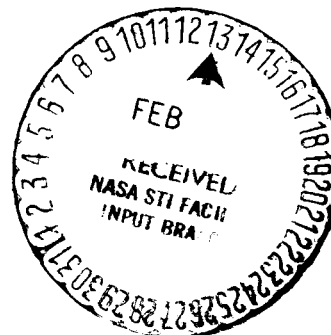
APOLLO MISSION 4/AS-501 TRAJECTORY RECONSTRUCTION
AND POSTFLIGHT ANALYSIS

VOLUME I

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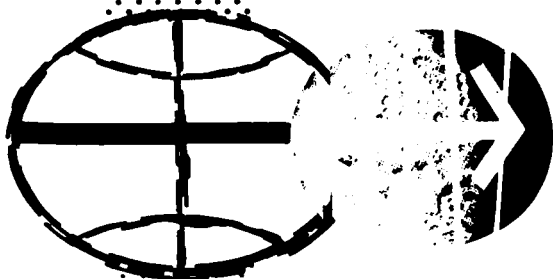
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APRIL 1968

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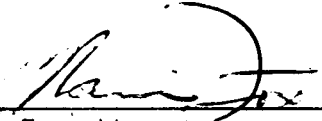
APOLLO MISSION 4/AS-501 TRAJECTORY RECONSTRUCTION
AND POSTFLIGHT ANALYSIS - APPENDIXES


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12 MARCH 1968

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
NAS 9-4810

Approved by 
D. H. Cooper, Manager
MSC/TRW Task A-50

Approved by 
M. Fox, Manager
Guidance and Control
Department

Approved by 
L. J. Skidmore, Manager
Systems Evaluation
Department

Approved by 
C. R. Coates
Assistant Project Manager
MTCP

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Supplement 1

APOLLO 4 MISSION REPORT

Supplement 1

APOLLO MISSION 4/AS-501 TRAJECTORY RECONSTRUCTION

AND POSTFLIGHT ANALYSIS

VOLUME I

April 22, 1968

Prepared by: TRW Systems Group

Approved by: George M. Low 4-22
George M. Low
Manager
Apollo Spacecraft Program Office

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

ABSTRACT

This report is submitted to the NASA Manned Spacecraft Center in accordance with Task MSC/TRW A-50.3 Contract NAS 9-4810. This report contains the postflight analysis performed in conjunction with the flight of Apollo Mission 4/AS-501/CSM 019, and is issued as a supplement to Section 3, Trajectory Section, of the Apollo Program Mission Report.

The report is issued in three volumes. Volume I contains details of the analysis and results obtained; Volume II contains the appendix material for Volume I, and Volume III presents a listing of the final NAT trajectory.

Volume III is available from microfilm on file with the Computations and Analysis Division, NASA-MSC.

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3. APOLLO MISSION 4/AS-501 TRAJECTORY RECONSTRUCTION AND POSTFLIGHT ANALYSIS

3.1 INTRODUCTION AND SUMMARY

AS-501 Mission

The AS-501/Apollo Mission 4 was launched from the Atlantic Missile Range at approximately 12:00:01 Greenwich mean time on 9 November 1967. The boost of the Saturn V and first burn of the S-IVB stage injected the combination S-IVB/CSM payload into a 100-nautical mile orbit. This parking orbit was continually perturbed by the liquid oxygen and hydrogen venting of the S-IVB stage. After two revolutions in this parking orbit, the S-IVB engines were restarted, and the combination payload was injected into a high-apogee, earth-intersecting ellipse. The S-IVB burn was closely followed by S-IVB/CSM separation and first burn of the service propulsion system (SPS) engine.

Approximately 2 hours and 18.5 minutes after the first SPS engine cutoff, the CSM spacecraft reached an apogee altitude of 9769 nautical miles on its earth intersecting orbit. At approximately 2 hours and 24 minutes after apogee, the SPS engines were reignited for a burn duration of 232 seconds to raise the entry velocity to that of a lunar return orbit. Approximately 2 minutes and 30 seconds after second SPS cutoff, CM/SM separation occurred, and 1 minute 24 seconds after separation, the service module entered the earth's atmosphere.

Figure 3-1 illustrates the mission timeline and the radar tracking coverage of the Apollo Mission 4 flight. In this figure, the time scale shifts at 04:00:00 ground elapsed time (16:00:01 Greenwich mean time) from 15-minute time intervals to 1-hour time intervals. The sequence of mission events is also shown in Table 3-1.

The AS-501 mission performed a near-nominal flight and successfully completed the primary objectives of demonstrating the following:

- Launch capability of the Apollo configuration Saturn V boost vehicle
- Restart capabilities of the S-IVB engine out of a coast parking orbit

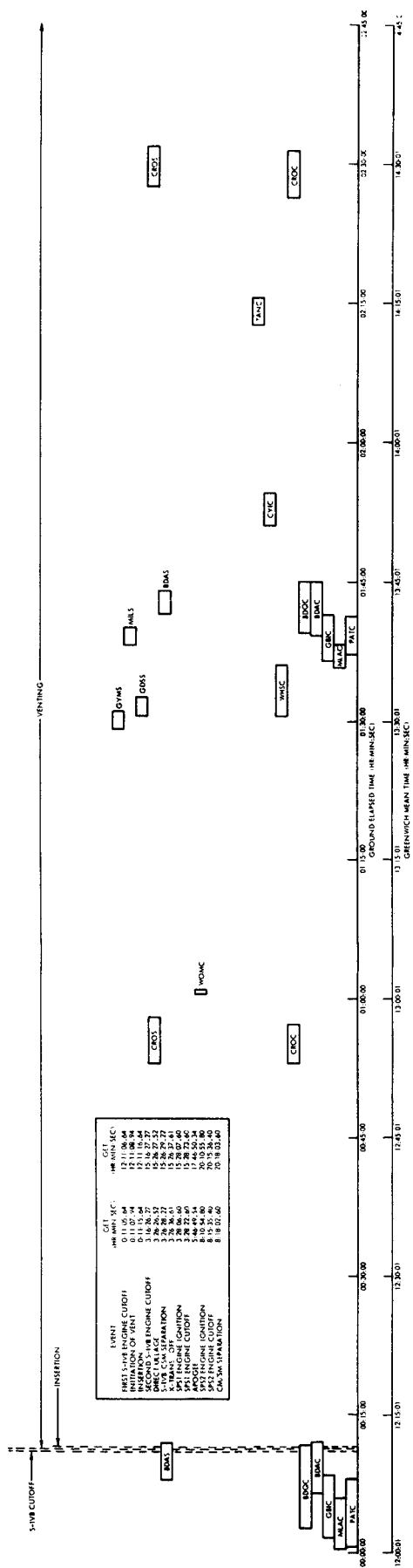


Table 3-1. Sequence of Events (Coast Phase)

<u>Event</u>	<u>Revolution</u>	<u>Date</u>	<u>Ground Elapsed Time (hr:min:sec)</u>	<u>Greenwich Mean Time (hr:min:sec)</u>
Second S-IVB Engine Cutoff	3	Nov. 9	3:16:26.27	15:16:27.27
Direct Ullage	3	Nov. 9	3:26:26.52	15:26:27.52
S-IVB/CSM Separation	3	Nov. 9	3:26:28.22	15:26:29.22
X-Transponder Off	3	Nov. 9	3:26:36.61	15:26:37.61
SPS 1 Engine Ignition	3	Nov. 9	3:28:06.60	15:28:07.60
SPS 1 Engine Cutoff	3	Nov. 9	3:28:22.60	15:28:23.60
Apogee	3	Nov. 9	5:46:49.54	17:46:50.54
SPS 2 Ullage	3	Nov. 9	8:10:26.36	20:10:27.36
SPS 2 Engine Ignition	3	Nov. 9	8:10:54.80	20:10:55.80
SPS 2 Engine Cutoff	3	Nov. 9	8:15:35.40	20:15:36.40
CM/SM Separation	3	Nov. 9	8:18:02.60	20:18:03.60
Entry (400,000 ft)	3	Nov. 9	8:19:28.54	20:19:29.54

- Restart capabilities of the SPS engine
- Entry characteristics of the CM at lunar return velocities

Analysis

This report presents the details and results of the postflight analysis of data taken during this mission. These data include the following:

- Radar tracking data
 - MSFN C-band
 - Unified S-band
 - Skin track

- Downlink telemetry data
 - S-IVB inertial unit
 - CSM inertial measuring unit
- GLOTRAC high-speed tracking:
 - Ascent phase
 - 2nd S-IVB engine burn

Ascent

An evaluation of the Apollo inertial guidance system performance has been made in order to determine the systematic errors present. The magnitudes of these errors were then used to reconstruct the trajectory from G&N data during SPS powered flight and entry.

Two sources of external trajectory data were available during ascent. Differences between the corrected G&N trajectory and (1) the S-IVB guidance data and (2) GLOTRAC high-speed tracking data are discussed in Section 3.2 and Appendix K.

Parking Orbit

The two-revolution coast parking orbit, prior to S-IVB engine restart, has been reconstructed for the purpose of verifying the Marshall Space Flight Center derived vent polynomials. These are polynomial estimates of the accelerations resulting from venting of the S-IVB stage. The details of the reconstruction and of the comparison/verification are included in Section 3.3 and Appendix J, with a listing of this parking orbit trajectory given at 10-minute intervals plus event times included as Appendix A.

Second S-IVB Engine Burn

Since both S-IVB guidance data and GLOTRAC high speed tracking data were available during the second S-IVB burn, additional comparisons with Apollo G&N data were made. Analysis of these comparisons supplement the Apollo IMU error evaluation which is based primarily on ascent. Corrected G&N trajectory residual plots are given in Section 3.3 and Appendix K.

Coast Phase

The AS-501 mission has been reconstructed from time of S-IVB engine cutoff to entry. The analysis of this reconstruction is given in Section 3.4, and the trajectory is presented at 10-minute intervals plus event times in Appendix B of this report.

SPS-2 and Reentry

The entry trajectory has been reconstructed using G&N data from SPS-2 ullage to splashdown. The reconstruction was accomplished using Apollo IMU errors determined from the ascent and second S-IVB burn evaluation. Discussion of the accuracy of the entry trajectory is presented in Section 3.5.

RTCC Compares

The Real Time Computing Center state vectors have been compared to the postflight reconstructed trajectories at RTCC anchor times from insertion to entry for the purpose of aiding the Real Time Center in evaluating fit procedures. The details of these comparisons are presented in Section 3.6.

3.2 LAUNCH

Corrected Apollo Guidance and Navigation (G&N) Boost Trajectory

Comparisons between the corrected G&N trajectory and the selected boost phase best estimate trajectory (BET) are presented graphically in Figures 3-2 through 3-7. The insertion vector obtained from the corrected G&N trajectory is compared in Table 3-2 with that obtained from the ESPOD orbital integration program and from tracking data. Finally, Table 3-3 contains a listing of the Apollo IMU errors used to correct the G&N trajectory.

In arriving at a corrected trajectory, it was necessary to derive a set of IMU performance errors which would best account for the disagreement occurring between the G&N and the "true" trajectory for all phases of the flight. A principal difficulty was that of determining the most accurate trajectory from among several sources. In the boost phase there were

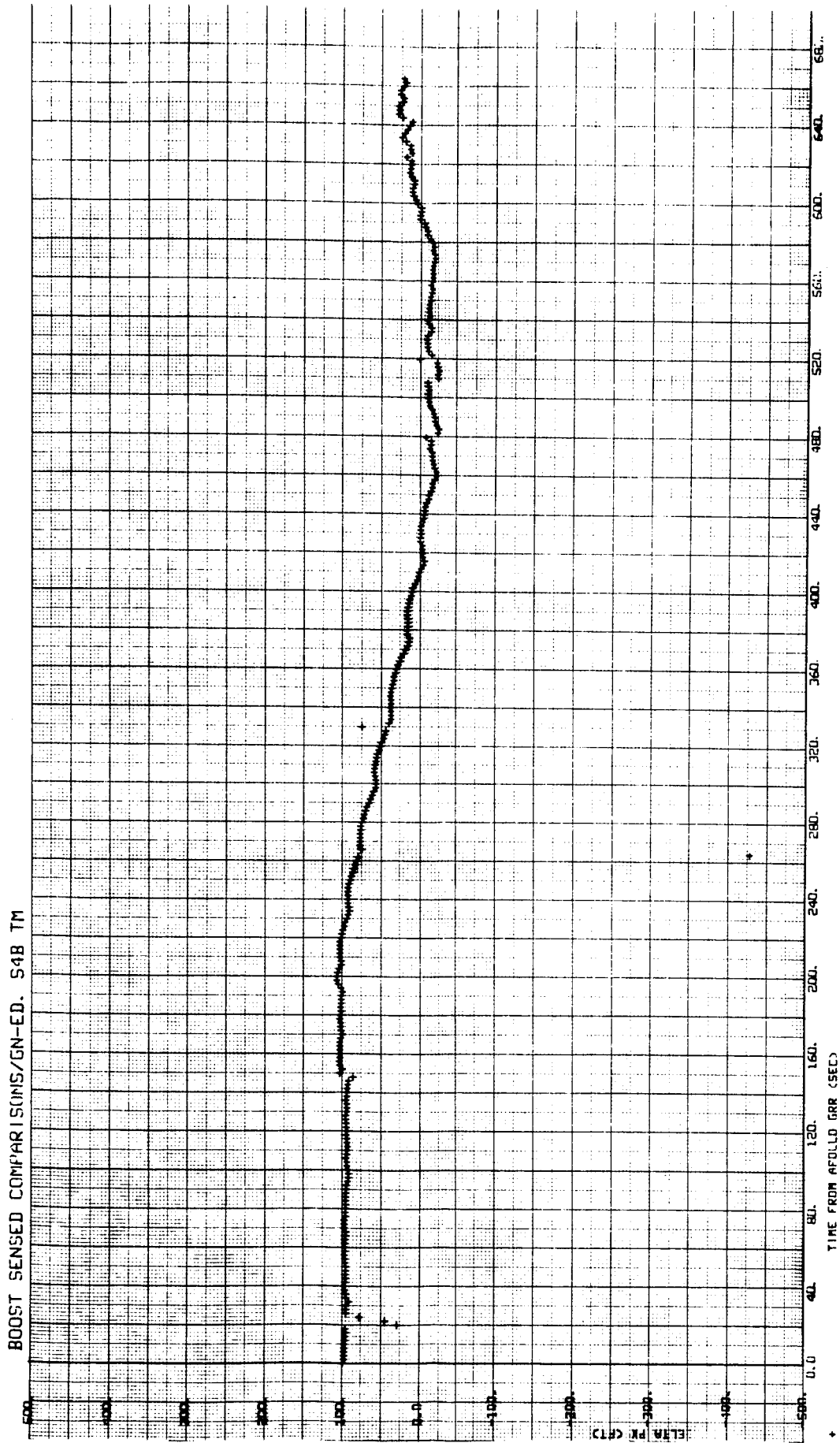


Figure 3-2. Boost Sensed
Comparisons/GN-ED.
S4B TM;Delta PX

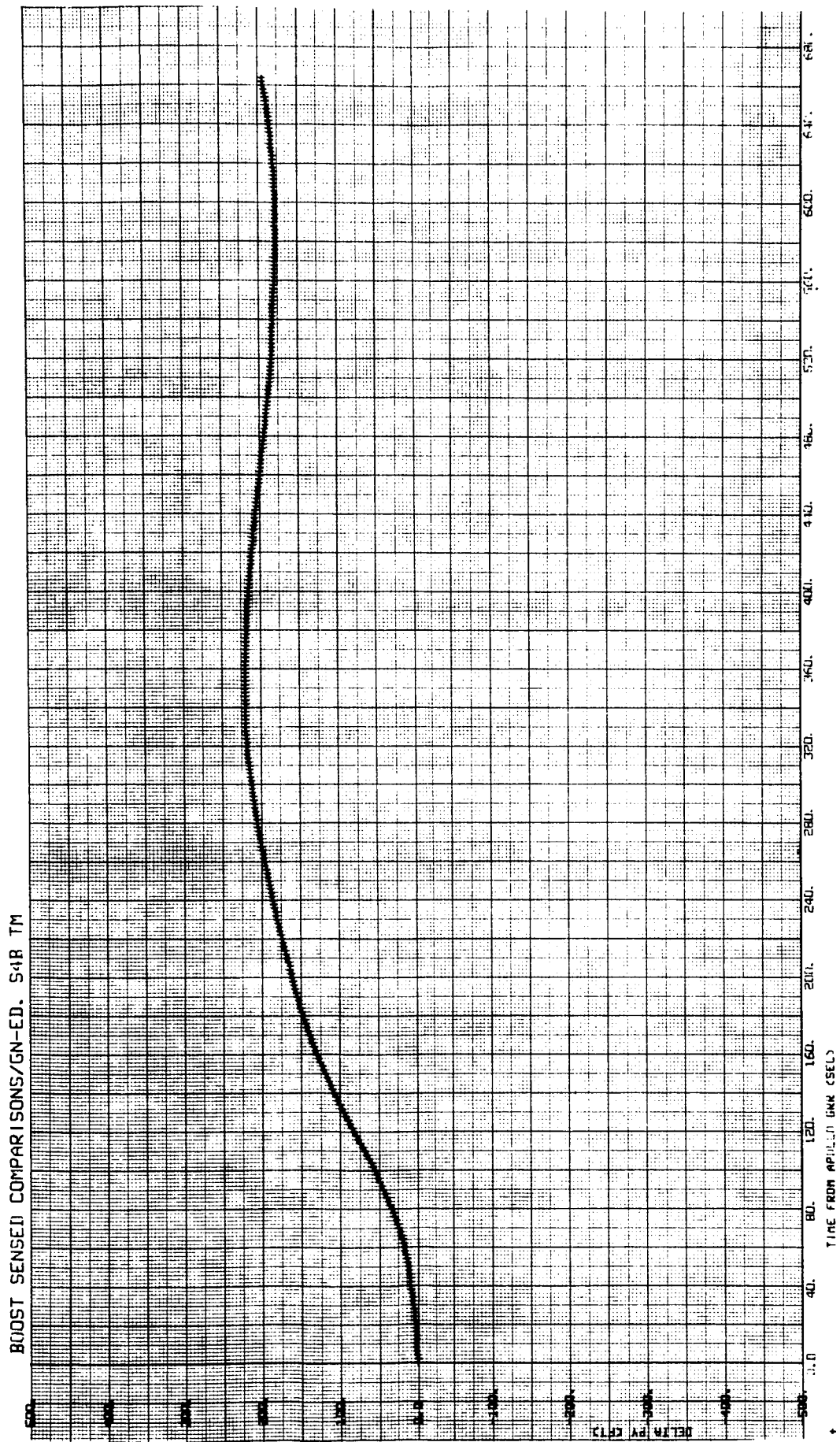


Figure 3-3. Boost Sensed
Comparisons/GN-ED.
S4B TM; Delta PY

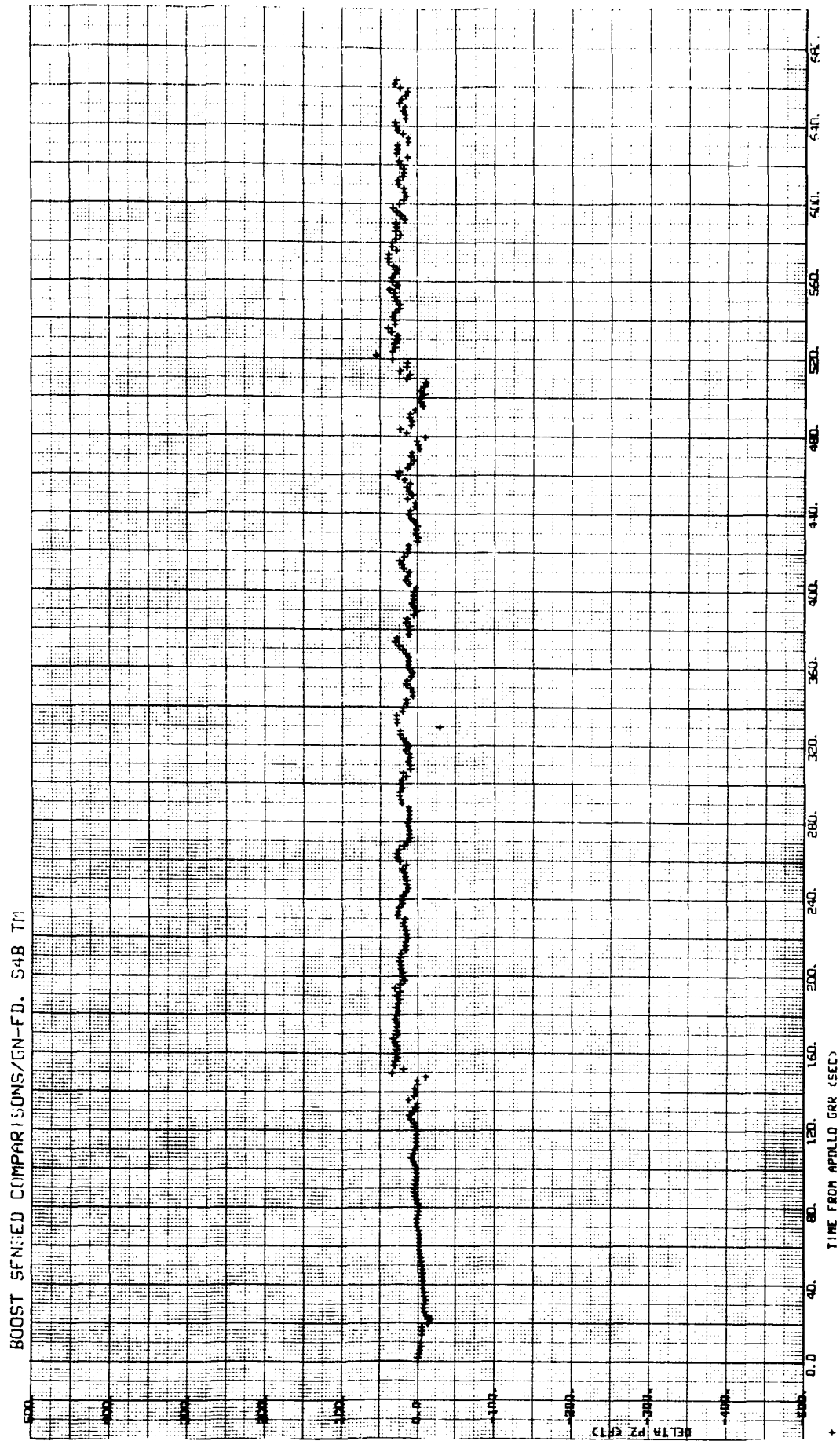


Figure 3-4. Boost Sensed
Comparisons/GN-ED.
S4B TM; Delta PZ

BOOST SENSED COMPARISONS/GN-ED. S4B TM

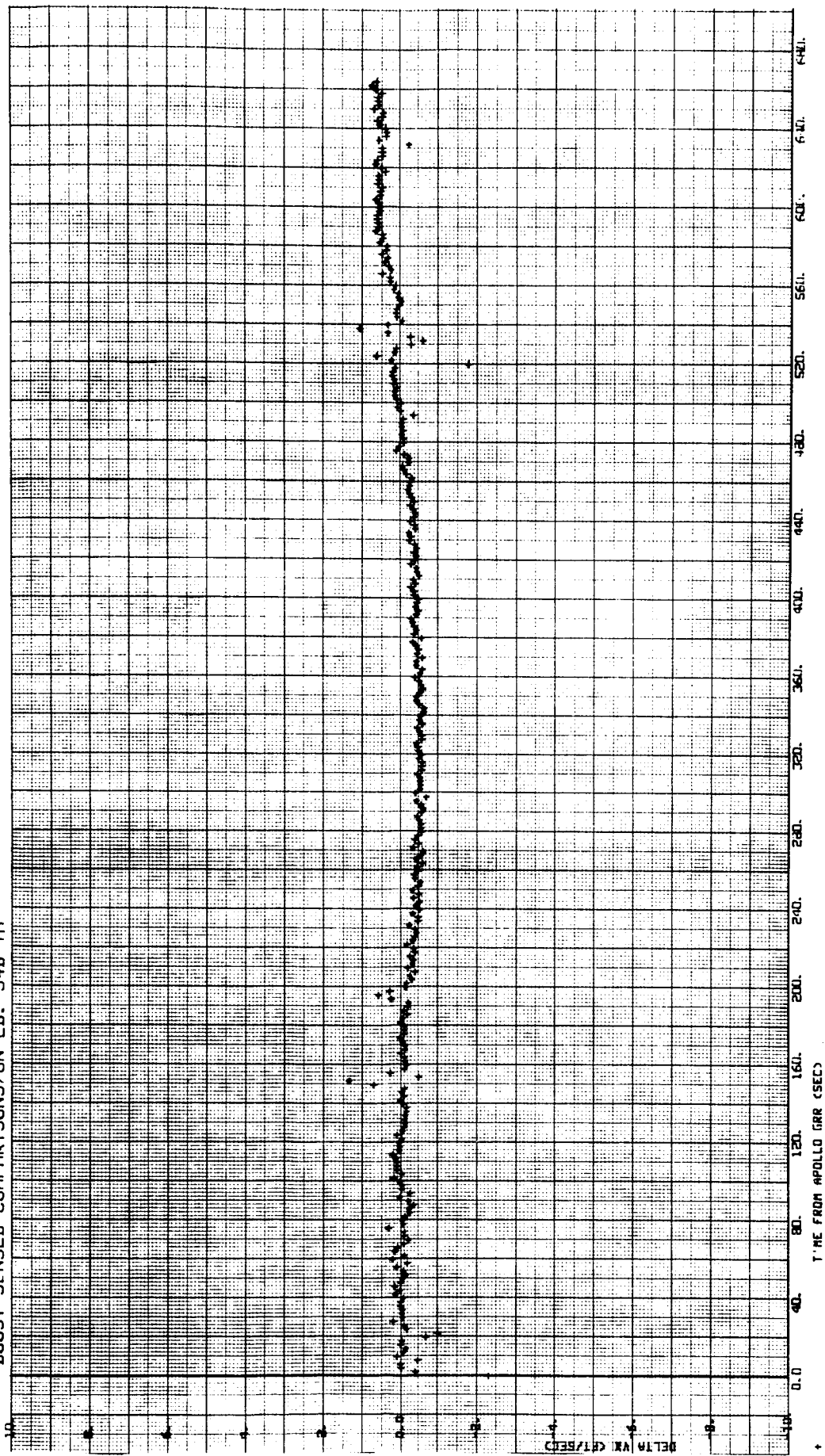


Figure 3-5. Boost Sensed
Comparisons/GN-ED.
S4B TM; Delta Vx

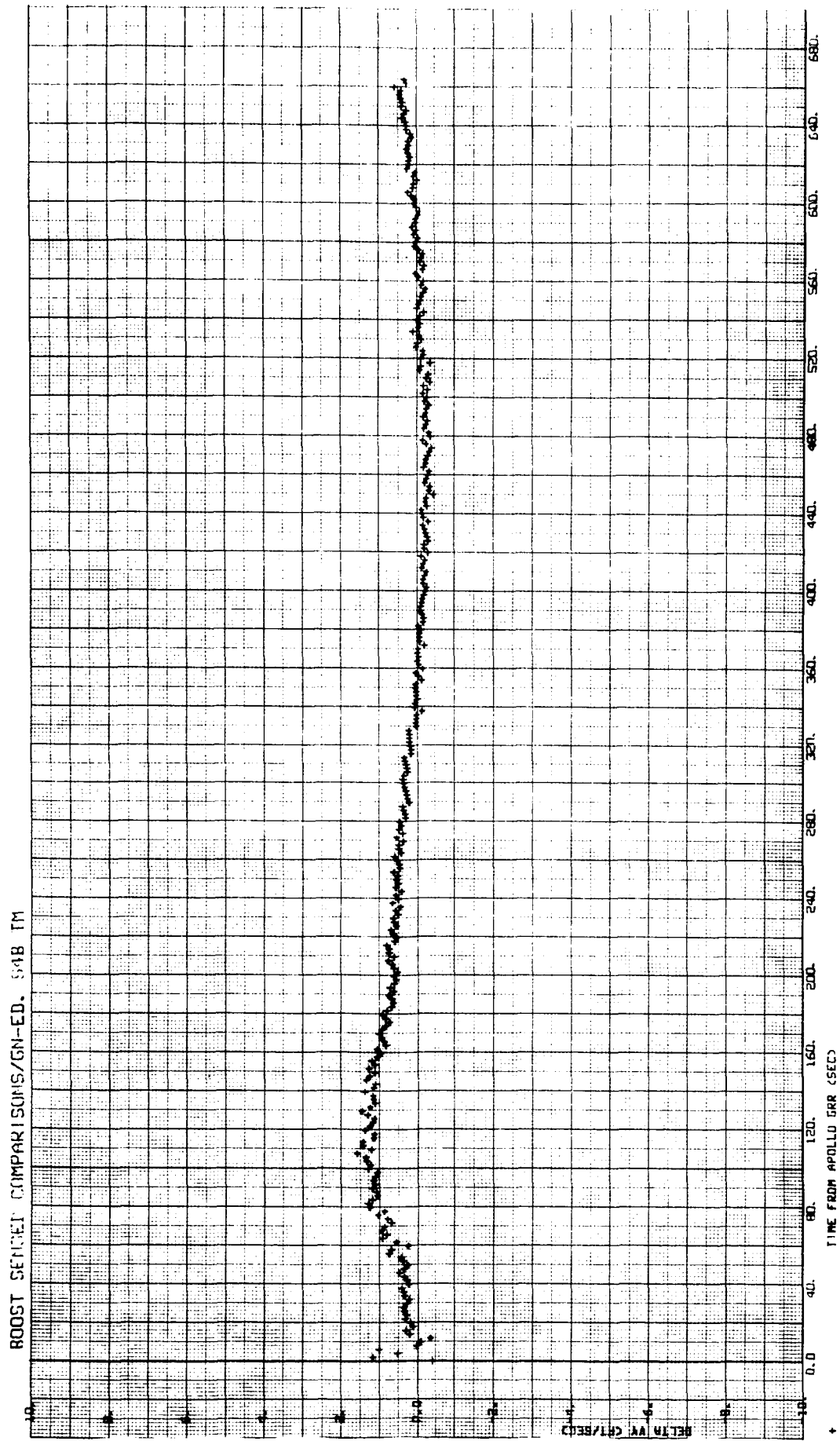


Figure 3-6. Boost Sensed
Comparisons/GN-ED.
S4B TM; Delta VY

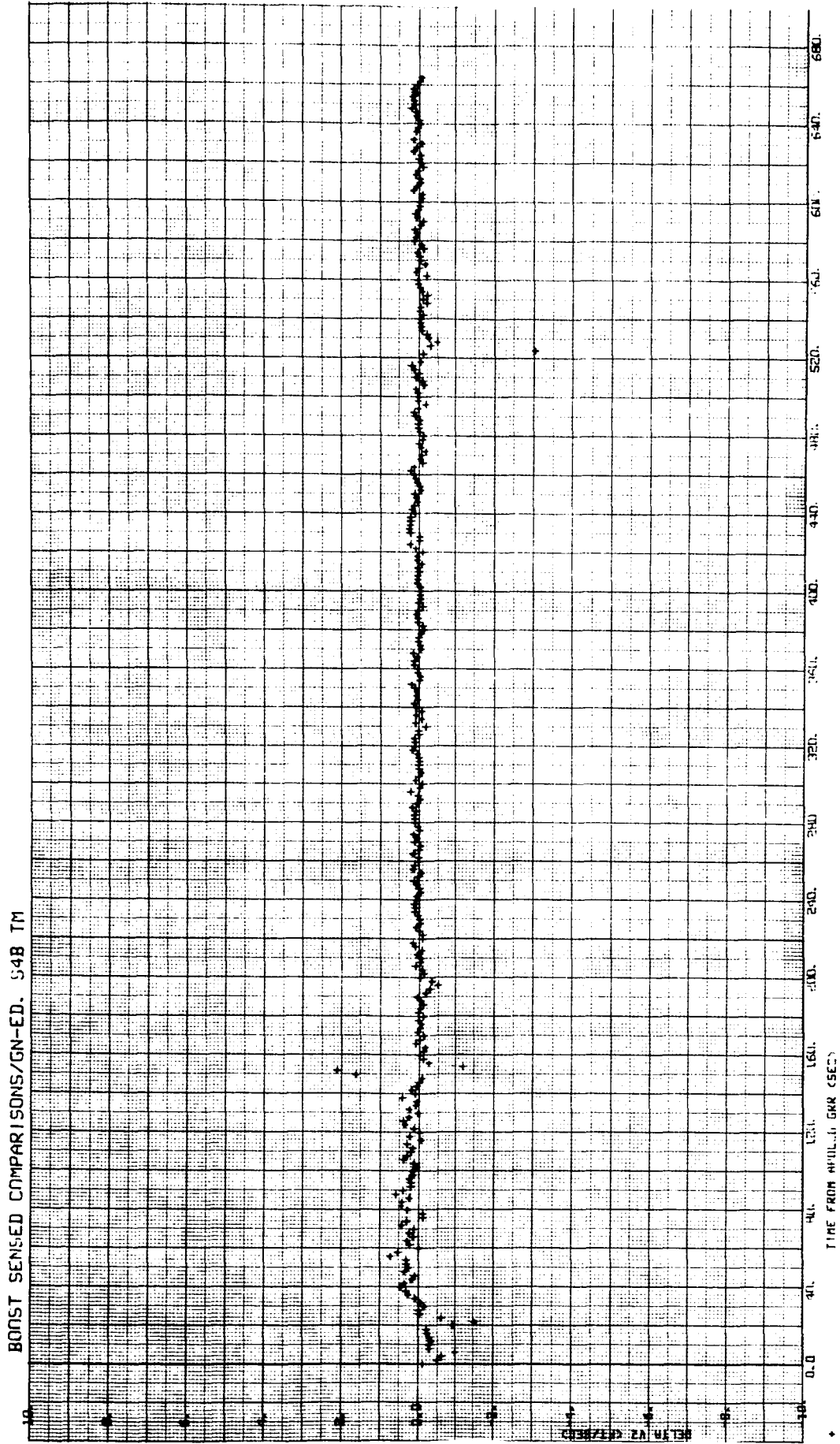


Figure 3-7. Boost Sensed
Comparisons/GN-ED.
S4B TM; Delta VZ

Table 3-2 . State Vector Comparisons in ECIG ($t_o = t_{GRR}$)
Coordinates

	S-IVB Cutoff ($t = 666$ seconds)		
	<u>ESPOD</u>	<u>Corrected G&N</u>	<u>Residuals</u> (G&N minus ESPOD)
PX	11, 040, 522. 0	11, 043, 073. 0	2, 551. 0
PY	-14, 429, 463. 0	-14, 428, 225. 0	1, 238. 0
PZ	11, 560, 363. 0	11, 556, 886. 0	-3, 477. 0
VX	19, 885. 9	19, 884. 2	-1. 7
VY	16, 033. 9	16, 039. 0	5. 1
VZ	1, 037. 5	1, 024. 8	-12. 7

three independent sources of vehicle trajectory data: the Apollo Guidance Computer, the S-IVB instrumentation unit (IU), and the GLOTRAC radar system. During the course of this analysis, several iterations of S-IVB and GLOTRAC trajectories were obtained from the responsible agencies and examined for reasonableness. It was concluded that the trajectory which was most physically reasonable during boost was that obtained from the edited S-IVB IU telemetry data.

The above conclusion was based on several observations. Velocity comparisons with the GLOTRAC trajectory provided to TRW by MSC revealed GLOTRAC data fluctuations of an erratic and physically unacceptable nature. An example of this is provided in the velocity comparison profile BOOST/SENSED COMPARISONS/GN-GLOTRAC included in Appendix K.

The S-IVB trajectories provided to TRW by MSFC included a series of variants of the original S-IVB data. The first such trajectory consisted of a simple editing (or smoothing) of the S-IVB telemetry data. The final such trajectory (as of the date of this report) was derived by forcing the end point of the S-IVB trajectory to fit a single end point (insertion vector) obtained from orbital integration programs. Examination of velocity comparisons with the G&N trajectory revealed discrepancies so large that

they could be accounted for only by postulating a physical failure of the Apollo IMU or a substantial and systematic error in the "final" S-IVB trajectory. Since there were no additional supporting indicators of an IMU failure, suspicion centered on the inaccuracy of the final S-IVB trajectory. In a subsequent telephone conversation with MSFC, it was confirmed that the S-IVB trajectory in question was known to be in error and was undergoing major revisions. A revised final S-IVB trajectory is not presently available. However, TRW was informed that the edited S-IVB IU telemetry data were thought to be fairly representative of the actual ascent trajectory. For that reason, these data were selected as the standard of comparison from which Apollo IMU performance errors were derived.

It is recognized that performance errors probably also existed in the S-IVB IMU. Therefore, the Apollo IMU error set derived by comparisons of the AGC and S-IVB trajectories will be incorrect by the amount of these S-IVB errors. However, the corrected G&N trajectory agrees well with independent sources during both the second S-IVB burn phase and reentry. It is therefore concluded that the S-IVB errors were relatively small (as was expected) and that the derived Apollo IMU error set is reasonably accurate.

Comparisons of the corrected G&N trajectory with the other boost trajectories referred to above are presented graphically in Appendix K.

Shown in Table 3-3 is a list of the Apollo IMU errors derived to best minimize the residuals between the G&N trajectory and the most reliable BET in all mission phases. The fit to each phase was weighted so that the best fit was obtained where the most reliable standard existed. Table 3-3 also includes the results of error parameter measurements and the AGC compensation values loaded for the flight, where applicable. As can be seen from the table, the great majority of the derived error values agree with their measured values within the one sigma sample standard deviation. In general, those errors which satisfy that constraint are not treated further. However, a discussion of deduced errors which substantially exceed that value and for which additional data are available may be found in the TRW Project Technical Report 05952-H394-R0-00, (Task E-38), "AS-501 Guidance and Navigation Error Analysis."

Table 3-3. Apollo IMU Errors

Parameter	Value Used	1 σ Measured Uncertainty (GSOP)	Compensation Values		Data Mean	Final Preflight Measurements	Comments
			1 σ Measured Uncertainty (GSOP)	(Data Load in AGC Computer)			
VOX	-1.7 ft/sec	NA	NA	NA	NA	NA	
BX	-91.4 μ g	408.0	418	418	418	515.0	
BY	11.3 μ g	408.0	204	204	204	132.0	
BZ	-110.0 μ g	408.0	-286	-286	-286	-85.6	
ZSF	191 ppm	150.0	139	139	139	44.0	
XZMSL	-43 arc sec	29.8	None	None			Measured -69 (GSOP)
YXMSL	-45 arc sec	29.8	None	None			Measured -14 (GSOP)
YZMSL	13 arc sec	29.8	None	None			Measured +13 (GSOP)
ZXMSL	-20 arc sec	29.8	None	None			Measured +0 (GSOP)
XGCDR	-0.043 deg/hr	0.045	0.0225	0.0225	0.0225	-0.0214	
YGCDR	0.0584 deg/hr	0.045	-0.096	-0.096	-0.101	-0.104	
ZGCDR	0.00245 deg/hr	0.045	-0.114	-0.114	-0.114	-0.125	
XADIA	-0.036 deg/hr/g	0.12	-0.095	-0.095	-0.055	-0.09	
ZADIA	0.70 deg/hr/g	0.12	0.310	0.310	0.312	0.893	See test (Sect. 3.1.1.1.4)
YADSR	0.08 deg/hr/g	0.075	0.069	0.069	0.069	0.098	
XADOA	0.0445 deg/hr/g	0.064					
ZIASQ	-0.15 deg/hr/g ²	NA	None	None			0.0345 measured preflight
PHIX	74.0 arc sec	103.0	None	None			
PHIZ	-5 arc sec	5.0	None	None			

Examination of Table 3-2 reveals a significant disagreement between the corrected G&N and ESPOD vectors at the time of S-IVB cutoff. This divergence may be partially explained by observing that the ESPOD reconstruction relies on a relatively few (nine) radar data points near insertion and is not expected to be highly accurate in that region. Agreement is considerably better at times where accurate ESPOD vectors or other BET data are available (second S-IVB burn cutoff and entry). This is discussed further in Sections 3.3 and 3.4.

3.3 PARKING ORBIT

For the AS-501 mission, TRW Task A-50 was requested to reconstruct the two-revolution parking orbit phase of the flight using the MSFC derived polynomials as an aid to MSFC in evaluating this modeling technique. This section presents the reconstruction of the parking orbit phase of the flight and lists the results of the evaluation of the MSFC vent polynomial model.

Sequence of Events

Lift-off for the Saturn V vehicle occurred at 12 hours, 0 minutes, and 1 second on 9 November 1967. At 11 minutes and 5.64 seconds ground elapsed time (GET referenced to range zero), Saturn IVB engine cutoff occurred. This was immediately followed by the initiation of vent at 11 minutes and 7.94 seconds, GET. The Saturn IVB/command service module (S-IVB/CSM) was inserted into a 100-nautical mile circular orbit at 11 minutes and 16.64 seconds, GET. For almost two revolutions there was a continuous vent of liquid oxygen and liquid hydrogen. At 3 hours, 6 minutes, and 7 seconds, GET, S-IVB attitude orientation and preignition sequence began in preparation for translunar injection (TLI). Finally, the second S-IVB engine ignition occurred over the Eastern Test Range (ETR) at 3 hours, 11 minutes, and 27.57 seconds, GET.

For convenience, Table 3-4 lists the major events during the parking orbit along with the ground elapsed time and Greenwich mean time (GMT) associated with each event.

Table 3-4. Sequence of Events (Parking Orbit)

<u>Event</u>	<u>Revolution</u>	<u>Date</u>	<u>Ground Elapsed Time (hr:min:sec)</u>	<u>Greenwich Mean Time (hr:min:sec)</u>
First S-IVB Engine Cutoff	1	Nov. 9	0:11:05.64	12:11:06.64
Initiation of Vent	1	Nov. 9	0:11:07.94	12:11:08.94
Insertion	1	Nov. 9	0:11:15.64	12:11:16.64
Second S-IVB Engine Cutoff	3	Nov. 9	3:11:26.57	15:11:27.57

Data Processing

A magnetic tape containing low speed radar tracking data (C-band and S-band) was received from MSC on the evening of November 9. The MATAG program converted the data into a format compatible with ESPOD and generated a time-ordered master data tape. The EDG program edited the master data tape in the following manner:

- a) Deleted all data flagged invalid
- b) Deleted all data with elevations below 3 degrees
- c) Refracted all range and angle data using the mean monthly value for surface refractivity for each station
- d) Subtracted 123 feet from all IU range data
- e) Sorted data by object, i. e., S-IVB transponder, CSM transponder, and skin track
- f) Output radar observation cards

This data processing was essentially completed in one day.

There were two problem areas. First, MATAG did not at this time have the capability to process radar data from mobile tracking sites (ships); second, MATAG did not test on object number when processing doppler data. Thus, it was unable to convert doppler data in the dual

mode. It is hoped that these two deficiencies will be corrected for AS-204/LM-1 mission.

Table 3-5 summarizes the EDG output which is radar observation cards. The table lists the station identification, the revolution, the date, the rise time, rise elevation, maximum elevation of the pass, set time, set elevation, and the total number of observations.

A summary of the data that were flagged invalid at the station is presented in Appendix I.

Orbital Fit Discussion

Before each fit is discussed in detail, a few assumptions concerning these fits should be stated. First, it is assumed that all stations are in perfect time synchronization with one another, unless otherwise noted. Second, it is assumed that all the data are time tagged on the received pulse; thus, the light time correction retards the time tag of the data. Third, it is assumed that a 0.06-second timing bias added to all tracking data accounts for the difference between UT1 and UTC for 9 November 1967.

Table 3-5. Summary of Radar Observations for the Parking Orbit

Station	Revolution	Date (yr:mo:day)	Rise Time, GMT (hr:min:sec)	Rise* Elevation (deg)	Maximum* Elevation (deg)	Set Time, GMT (hr:min:sec)	Set* Elevation (deg)	Number of Observations
MLAC	1	67:11:09	12:00:30	3.4	37.5	12:06:06	10.4	57
PATC	1	67:11:09	12:00:42	3.4	26.0	12:08:00	3.0	70
GBIC	1	67:11:09	12:01:42	3.0	21.2	12:08:24	2.9	68
BDQC	1	67:11:09	12:05:18	3.9	73.3	12:11:48	3.9	54
BDAC	1	67:11:09	12:06:24	8.6	73.3	12:12:00	3.0	57
BDAS	1	67:11:09	12:08:06	29.1	72.3	12:11:54	3.4	39
CROS	1	67:11:09	12:52:54	2.5	9.3	12:58:06	3.0	45
CROC	1	67:11:09	12:53:00	2.9	8.5	12:57:18	2.9	44
WOMC	1	67:11:09	13:00:24	75.7	75.7	13:00:54	36.6	6
GYMS	1	67:11:09	13:29:06	5.3	26.1	13:31:06	26.1	17
WHSC	1	67:11:09	13:30:30	3.2	19.5	13:35:54	2.9	54
GDSS	1	67:11:09	13:30:36	3.8	4.8	13:32:36	3.8	18
MLAC	2	67:11:09	13:35:48	3.1	21.3	13:38:24	21.3	25
GBIC	2	67:11:09	13:36:30	2.8	13.5	13:41:36	3.2	52
PATC	2	67:11:09	13:37:12	11.2	20.5	13:41:24	2.7	56
MILS	2	67:11:09	13:38:06	18.8	23.6	13:39:54	11.0	8
BDAC	2	67:11:09	13:39:12	3.1	89.5	13:45:06	3.0	36
BDQC	2	67:11:09	13:39:24	4.1	83.0	13:45:06	3.1	54
BDAS	2	67:11:09	13:41:24	30.0	83.3	13:44:06	10.2	28
CYIC	2	67:11:09	13:51:00	6.3	6.3	13:54:36	3.0	37
TANC	2	67:11:09	14:12:36	31.2	31.2	14:15:30	3.1	16
CROC	2	67:11:09	14:26:12	2.9	12.4	14:31:12	2.8	51
CROS	2	67:11:09	14:27:24	8.2	12.4	14:31:48	3.0	22
HAWC	2	67:11:09	14:51:36	2.9	9.8	14:56:12	2.9	47

* These elevations represent refracted elevations.

Table 3-5. Summary of Radar Observations for the Parking Orbit (Continued)

Station	Revolution	Date (yr:mo:day)	Rise Time, GMT (hr:min:sec)	Rise* Elevation (deg)	Maximum* Elevation (deg)	Set Time, GMT (hr:min:sec)	Set* Elevation (deg)	Number of Observations
HAWS	2	67:11:09	14:53:24	9.1	9.8	14:57:00	3.0	17
CALC	2	67:11:09	15:00:30	2.9	19.6	15:05:54	3.6	45
GDSS	2	67:11:09	15:02:12	7.6	19.6	15:07:00	3.7	46
WHSC	2	67:11:09	15:05:18	26.0	85.6	15:08:24	6.8	32
TEXS	2	67:11:09	15:08:00	17.1	17.1	15:09:00	10.8	9
PATC	2	67:11:09	15:09:12	3.4	26.0	15:17:18	3.0	81
GBIC	3	67:11:09	15:09:48	2.9	19.8	15:15:12	9.8	55

*These elevations represent refracted elevations.

Table 3-6 lists the values used by the TRW orbit determination program (ESPOD) to weight the radar tracking data from each station as a function of data type and radar type.

Table 3-6. Radar Data Weighting (Parking Orbit)

<u>Data Type</u>	<u>Type of Radar</u>	<u>Weighting</u>
R:A:E	FPQ-6	60 ft: 0.0258 deg: 0.0258 deg
R:A:E	TPQ-18 and FPS-16	90 ft: 0.0354 deg: 0.0354 deg
R:A:E	MPS-26	180 ft: 0.1720 deg: 0.1720 deg
R:X:Y	USB: 30-ft antenna 85-ft antenna	90 ft: 0.1375 deg: 0.1375 deg
Doppler (2 way)	USB: 30-ft antenna 85-ft antenna	0.2 cycle/sec

A summary of station locations for both C-band and S-band stations can be found in Appendix H.

The S-IVB/CSM trajectory for the parking orbit was reconstructed using low speed C-band tracking data and the TRW orbit determination program. The vent was modeled by generating a vent acceleration tape from the vent acceleration polynomials derived by MSFC. A table of the X, Y, and Z MSFC vent polynomial coefficients and the time interval for which these coefficients are valid is to be found in Appendix J. Also in this appendix is the MSFC plot comparison of the telemetered velocity and the fit velocity polynomials. The vent acceleration tape is then input into the version of ESPOD which has the burn models (IGS ESPOD), and the vent is treated as if it were a burn. It should be noted that the vent polynomials have already accounted for drag, thus the drag parameter is input as zero. Only C-band data were used in the reconstruction, since IGS ESPOD is unable to handle the S-band data.

The parking orbit begins at S-IVB/CSM insertion (12 hours, 11 minutes, and 16.64 seconds, GMT) and ends at the second S-IVB engine ignition (15 hours, 11 minutes, and 27.57 seconds, GMT). For the purposes of determining a trajectory, the parking orbit was divided into two segments. Table 3-7 presents a summary of information pertinent to each fit. For each fit the following information is listed: the observation span of the data, the data used in the fit, the solution vector, and the trajectory output.

Segment 1 was reconstructed using all available C-band data, and covers the period from S-IVB/CSM insertion (12 hours, 11 minutes, and 16.64 seconds, GMT) to the beginning of revolution 2 (13 hours, 39 minutes, and 12 seconds, GMT). A least-squares fit was made where the state vector and the accelerometer bias vector comprised the solution vector. The recovered accelerometer bias values were 0.27×10^{-3} feet per second per second for X, 0.12×10^{-3} feet per second per second for Y, and -0.36×10^{-3} feet per second per second for Z where X is collinear with the local vertical at launch, Z is collinear with the firing azimuth at launch, and Y completes a right-handed system.

The most significant data problem occurred at CROCO1 where the mean monthly value of surface refractivity (329) used in the refraction routine was considerably different than the computed value (367) based upon measured temperature, pressure, and dew point data; consequently, the CROC elevation data was weighted out of the fit.

Table 3-8 lists the residual mean and RMS by station and type for Segment 1 where all quantities are defined as usual, and N represents the number of data points for a particular type of observable.

The trajectory was generated at 10-minute intervals and at event times. The trajectory listing can be found in Appendix A.

The residual plots for this fit can be found in Appendix C where pertinent comments will be made for each plot, if applicable.

Table 3-7. Orbital Fit Summary (Parking Orbit)

<u>Segment</u>	<u>Date</u>	<u>Observation Span, GMT (hr:min)</u>	<u>Station/Pass</u>	<u>Solution Vector</u>	<u>Trajectory Output</u>
1	Nov. 9	12:11 - 13:39	BDAC01, CROCO1, WHSCO1, MLACO2, GBICO2, and PATCO2.	State Vector and Accelerometer Biases	10-min intervals and at event times
2	Nov. 9	13:39 - 15:11	PATCO2, BDACO2, GBICO2, BDAQO2, CROCO2, HAWCO2, CALCO2, WHSCO2, PATCO3, and GBICO3.	State Vector and Accelerometer Biases	10-min intervals and at event times

Table 3-8. Residual Mean and RMS by Station and Type for Segment 1 (Parking Orbit)

<u>Station/Pass</u>	<u>Transponder</u>	<u>Range</u>	<u>Azimuth</u>	<u>Elevation</u>	
BDACO1	S-IVB	0.330873E 01	-0.465439E-02	-0.179988E-01	Mean
		0.418733E 02	0.660262E-02	0.1516783-01	RMS
		9	9	9	N*
CROCO1	CSM	0.954056E 00	-0.460417E-03	0.153903E-01	Mean
		0.133825E 02	0.551251E-02	0.805768E-02	RMS
		44	44	44	N*
GBICO2	S-IVB	0.152637E 03	-0.147478E-01	-0.544635E-02	Mean
		0.359778E 02	0.225931E-02	0.719975E-02	RMS
		23	23	23	N*
MLACO2	CSM	0.604464E 02	-0.442425E-02	-0.665531E-02	Mean
		0.323494E 02	0.408139E-02	0.104489E-01	RMS
		24	24	24	N*
PATCO2	SKIN	-0.752212E 02	-0.654739E-02	-0.582545E-02	Mean
		0.516004E 02	0.528070E-02	0.834461E-02	RMS
		20	20	20	N*
WHSCO1	CSM	0.157542E 02	0.153161E-01	-0.918419E-02	Mean
		0.378752E 02	0.116398E-01	0.786392E-02	RMS
		53	53	53	N*

* Number of data points

Segment 2 was reconstructed using all the available C-band data except for CYICO2 and TANCO2. The data from these stations were deleted from the fit because of strange residual patterns. Segment 2 covers the period from the beginning of the second revolution (13 hours, 39 minutes, and 12 seconds, GMT) to the second S-IVB engine ignition (15 hours, 11 minutes, and 27.57 seconds, GMT). A least-squares fit was made where the solution vector consisted of the state vector and the accelerometer bias vector. The recovered accelerometer bias values were -0.12×10^{-5} feet per second per second for X, 0.25×10^{-3} feet per second per second for Y, and -0.76×10^{-3} feet per second per second for Z, where the same definitions hold for X, Y, and Z as in the discussion of Segment 1. The CROCO2 elevation data were weighted out of the fit because of the previously discussed refraction problem.

The residual mean and RMS by station and type for Segment 2 is listed in Table 3-9.

The trajectory was generated at 10-minute intervals and at event times. The trajectory can be found in Appendix A.

The residual plots for the fit can be found in Appendix C, where pertinent comments will be made for each plot, if applicable.

A two-revolution fit was made of the parking orbit using the C-band data except for CYICO2 and TANCO2. It was found that this trajectory compared favorably (differing less than 500 feet in total position and 1 foot per second in total velocity) with the trajectories for both Segment 1 and Segment 2 except for the insertion vector (12 hours, 11 minutes, and 16.64 seconds, GMT). It was not possible to fit the BDACO1 data as well with the two-revolution fit as it was with the Segment 1 fit without heavily weighting the BDACO1 data. Also, the Segment 1 trajectory and the Segment 2 trajectory differed by only 167 feet in total position and 0.52 foot per second in total velocity at the beginning of revolution 2. Therefore, it was decided that the two-revolution parking orbit would be best represented by the Segment 1 and the Segment 2 trajectories.

Table 3-9. Residual Mean and RMS by Station and Type for Segment 2 (Parking Orbit)

<u>Station/Pass</u>	<u>Transponder</u>	<u>Range</u>	<u>Azimuth</u>	<u>Elevation</u>	
BDACO2	S-IVB	-0.187820E 02	-0.126746E-01	-0.916021E-02	Mean
		0.402976E 02	0.122319E-01	0.145669E-01	RMS
		31	31	31	N*
BDQCO2	SKIN	0.175553E 02	0.278941E-02	-0.442571E-02	Mean
		0.383137E 02	0.254451E-01	0.185118E-01	RMS
		54	53	54	N*
CALCO2	CSM	-0.254772E 02	-0.706586E-02	-0.154213E-01	Mean
		0.818235E 02	0.552589E-02	0.583296E-02	RMS
		28	28	28	N*
CROCO2	CSM	-0.917116E-02	-0.1701571E-02	0.149194E-01	Mean
		0.169004E 02	0.401335E-02	0.777728E-02	RMS
		51	51	51	N*
GBICO2	S-IVB	0.482576E 02	-0.513371E-02	-0.153579E-01	Mean
		0.322966E 02	0.824301E-02	0.149075E-01	RMS
		41	41	41	N*
HAWCO2	CSM	0.439862E 01	0.963278E-02	-0.303457E-01	Mean
		0.361622E 02	0.983778E-02	0.110124E-01	RMS
		47	47	47	N*

* Number of data points

Table 3-9. Residual Mean and RMS by Station and Type for Segment 2 (Parking Orbit) (Continued)

<u>Station/Pass</u>	<u>Transponder</u>	<u>Range</u>	<u>Azimuth</u>	<u>Elevation</u>	
PATCO2	S-IVB	-0.185650E 02	0.143179E-03	-0.147649E-01	Mean
PATCO3	CSM	0.374906E 02	0.525055E-02	0.129614E-01	RMS
		46	46	46	N*
WHSCO2	SKIN	-0.303818E 02	0.867552E-02	-0.119603E-01	Mean
		0.460285E 02	0.273535E-01	0.286323E-01	RMS
		32	31	31	N*

*Number of data points

A detailed discussion of RTCC comparisons for Segment 1 and Segment 2 is presented in Section 3. 6.

The low speed S-band tracking residual plots using the reconstructed trajectories for Segment 1 and Segment 2 can be found in Appendix D. Pertinent comments will be made for each plot, if applicable. A version of ESPOD which does not have a vent model had to be used to generate the residuals. In order to minimize the effects of venting on the residuals, the propagation time of the vectors used to generate the residuals was minimized.

The quality of the S-band data was not as good as the C-band data in near-earth orbit. A detailed study of the S-band plots (Appendix D) will possibly distinguish operational problems from hardware problems.

Vent Polynomial Evaluation

The MSFC vent polynomials will not be evaluated explicitly; instead, the reconstructed trajectory which was based on these polynomials will be evaluated.

In general, the goodness of a trajectory is measured by how well the trajectory fits the observations. Tables 3-8 and 3-9 and the plots (Appendix C) indicate a good fit was obtained by TRW using the vent polynomials. The state vectors obtained in real time by the RTCC, if regarded as an independent check, are in good agreement with TRW during the parking orbit phase.

The evaluation of the MSFC trajectory will be based on two comparisons. First, the reconstructed trajectories will be compared by differencing state vectors at common time points; second, a comparison of the recovered accelerometer biases will be made.

MSFC transmitted to TRW Task A-50 a set of vectors for the parking orbit at the RTCC anchor times. The vector differences (MSFC - TRW) in the Apollo 4 standard coordinate system are listed in Table 3-10. For each vector comparison the following information is listed:

- The RTCC vector anchor time (GMT)
- The position component differences in feet and the velocity component differences in feet per second
- The total difference in position and velocity in feet and feet per second

The total position differences were generally around 2000 feet, although the differences were as high as 4000 feet at 14 hours, 26 minutes, and 12 seconds (CROCO2). The total velocity differences were as large as 5.06 feet per second at insertion (12 hours, 11 minutes, and 16.64 seconds, GMT) and as small as 0.84 foot per second at the second S-IVB engine ignition (15 hours, 11 minutes, and 27.57 seconds, GMT). The differences are not unreasonable, although the differences are somewhat higher than expected. However, these differences are not larger than the differences observed on the AS-203 mission which was used as a test case for the AS-501 mission.

For completeness, the MSFC vectors were also compared with the RTCC vectors (RTCC - MSFC) in the RTCC coordinate system. The results of these comparisons are listed in Table 3-11. Each RTCC vector compared is identified either by a station identification and batch number or by a descriptive word phrase. Also listed in the table are the RTCC vector anchor time (GMT), the position component differences in feet, the velocity component differences in feet per second, and the total difference in position and velocity in feet and feet per second.

The MSFC vectors compare favorably with the RTCC vectors in Table 3-11. The large differences between MSFC vectors and the special RTCC vectors in Table 3-11 were also observed between the TRW vectors and the RTCC special vectors (Section 3.6).

Table 3-12 compares the recovered accelerometer biases for Segment 1 and Segment 2. Also included is a comparison of the recovered accelerometer biases for the two-revolution fit described above.

Table 3-10. MSFC - TRW Vector Differences for the Parking Orbit

RTCC Anchor Time, GMT (hr:min:sec)	ΔX (ft)	ΔY (ft)	ΔZ (ft)	$\Delta \dot{X}$ (ft/sec)	$\Delta \dot{Y}$ (ft/sec)	$\Delta \dot{Z}$ (ft/sec)	ΔR (ft)	ΔV (ft/sec)
12:11:16.64	68.0	-1,983.0	766.0	2.99	3.57	-1.99	2,127	5.06
12:11:21.57	-322.0	-1,879.3	839.0	2.18	0.13	-2.81	2,083	3.56
12:11:22.25	-320.0	-1,889.4	838.0	2.21	0.13	-2.81	2,092	3.58
12:11:22.30	-320.0	-1,875.4	837.0	2.20	0.14	-2.81	2,078	3.57
12:11:24.00	-316.0	-1,876.7	832.0	2.20	0.14	-2.80	2,077	3.56
12:53:00.00	284.0	1,959.5	-855.0	-1.08	0.38	2.50	2,157	2.75
12:30:30.00	-459.0	-1,358.0	1,236.0	0.47	-1.49	-1.42	1,893	2.11
13:35:48.00	-285.0	-1,742.1	705.0	0.60	-0.93	-1.88	1,901	2.18
13:39:24.00	-146.0	-1,894.5	278.0	0.68	-0.45	-2.03	1,920	2.19
13:41:24.00	-33.0	-1,956.4	-145.0	0.72	0.38	-2.29	1,962	2.43
13:51:00.00	356.0	-1,245.0	-1,368.1	0.44	1.98	-1.74	1,884	2.67
14:26:12.00	-988.0	3,775.2	727.0	-2.33	0.61	4.00	3,969	4.67
14:26:18.00	-1,001.0	3,769.5	750.0	-2.36	0.56	4.00	3,972	4.68
14:54:00.00	-2,073.3	-334.0	2,776.6	1.81	-1.48	-2.41	3,481	3.36
15:05:18.00	-1,133.0	-178.5	924.0	0.51	1.43	-2.59	1,473	3.00
15:11:27.57	422.0	-273.0	187.0	-0.27	-0.76	0.24	536	0.84

Table 3-11. RTCC Vector Comparisons with MSFC

a) RTCC Vectors Comparisons								
Station/Batch	Anchor Time	X (ft)	Y (ft)	Z (ft)	\dot{X} (ft/sec)	\dot{Y} (ft/sec)	\dot{Z} (ft/sec)	ΔV (ft/sec)
BDACO4	12:11:24	737	-399	-613	7.61	-10.87	-9.10	16.14
BDASO8	12:11:24	554	-250	-1,298	0.39	3.25	-10.87	11.35
CROC11	12:53:00	36	-472	557	-1.54	0.58	-0.49	1.71
CROS13	12:53:00	-367	-804	1,321	-3.24	2.68	-5.23	6.71
WHSC18	13:30:30	363	-418	-1,440	-1.49	0.32	1.15	1.91
MLAC21	13:35:48	47	364	-303	-0.80	0.32	1.60	1.82
BDQC25	13:39:24	300	519	-241	-1.19	0.18	1.54	1.95
BDAS31	13:41:24	359	428	-127	-1.29	-0.23	1.62	2.09
CYIC30	13:51:00	-514	34	957	-2.17	-0.85	1.82	2.95
CROC32	14:26:12	858	-3,022	-1,259	1.15	-3.50	-2.78	4.62
WHSC47	15:05:18	-741	-908	101	-1.30	-0.50	2.78	3.11

Table 3-11. RTCC Vector Comparisons with MSFC (Continued)

b) Special Comparisons		<u>Anchor Time</u>	<u>X</u> (ft)	<u>Y</u> (ft)	<u>Z</u> (ft)	<u>\dot{X}</u> (ft/sec)	<u>\dot{Y}</u> (ft/sec)	<u>\dot{Z}</u> (ft/sec)	<u>ΔR</u> (ft)	<u>ΔV</u> (ft/sec)
<u>Vector Description</u>										
AGC Vector Insertion		12:11:21.57	-6,417	-278	16,813	-12.34	-1.54	-46.03	17,998	47.68
IP Raw Insertion		12:11:22.25	5,295	3,770	-787	0.08	-4.46	-15.20	6,547	15.84
USB Insertion		12:11:22.25	-382	1,601	-2,525	37.63	-74.33	0.30	3,014	83.31
IU Insertion		12:11:22.30	18,730	15,960	-5,244	14.51	14.31	7.15	25,160	21.59
Build AGC Navigation Update (BDQC25)		13:39:24.00	182	584	-207	-1.26	0.36	1.46	646	1.97
Best RTCC Vector Prior to TLI (WHSC47)		15:05:18.00	-741	-908	101	-1.30	-0.50	2.78	1,176	3.11

The table lists accelerometer biases in the X, Y, and Z directions for MSFC and TRW, where X is collinear with the local vertical at launch, Z is collinear with the firing azimuth at launch, and Y completes a right-handed system. The table shows that the accelerometer biases recovered by TRW and MSFC are consistent except for the X-accelerometer bias in Table 3-12b and the Y-accelerometer bias in Table 3-12c. The X-accelerometer bias is the only bias that does not have the same sign for all three tables.

In conclusion, it is felt that the vent polynomial technique is a good way to model vent. This conclusion was also reached after evaluating the vent polynomial technique using the four revolutions of the AS-203 mission as a test case.

Second S-IVB/ First Service Propulsion System Burn

In this phase, two G&N trajectory reconstructions were carried out. The set of derived Apollo IMU errors (Table 3-3) used to correct the G&N boost trajectory were used in these reconstructions.

Trajectory Comparisons

During the period of the second S-IVB burn, approximately 11,490 to 11,788 seconds from Apollo Guidance Reference Release (GRR), there were again three independent sources of trajectory data: Apollo G&N, the S-IVB instrument unit, and the GLOTRAC radar stations which service the Eastern Test Range. Comparisons were made between the sensed records of the corrected G&N trajectory and corresponding records from three sources: GLOTRAC, edited S-IVB instrument unit telemetry, and the final, corrected S-IVB trajectory (designated the S-IVB "Final Point Mass" trajectory by MSFC). The results of these comparisons are presented graphically in Figures 3-8 through 3-13 (for G&N minus GLOTRAC) and in Appendix K. Of the three reference trajectories with which comparisons were made, those made with the GLOTRAC data produced the most reasonable results. The error propagations suggested by these data seem more reasonable on physical grounds, although GLOTRAC data throughout the burn are erratic. The end point (11,788 seconds) sensed velocity residuals are 0.7, -6.5, and -3.6 feet per second in X, Y, and Z

channels, respectively, and agree fairly well with those taken from the final S-IVB Point Mass trajectories. However, the trend of the final S-IVB Point Mass comparisons strongly suggests that this agreement was brought about by forcing the S-IVB trajectory to fit tracking data closely near the end point of the burn.

Trajectory Reconstruction

After examining the results of the sensed trajectory comparisons described above, the derived Apollo IMU errors were used to reconstruct an Apollo G&N trajectory from time $t = 11,400$ seconds (prior to S-IVB ignition) through $t = 12,512$ seconds (after completion of the first SPS engine burn). This trajectory was initialized on an ESPOD state vector at $t = 11,400$ seconds, causing both the ESPOD and Apollo G&N trajectories to coincide initially. The purpose of this procedure was to determine how accurately the corrected G&N trajectory would track the BET over a substantial time interval. As can be seen from Table 3-13, the results of this comparison were fairly satisfactory.

It will be noticed that the last two sets of residuals (for $t = 12,480$ seconds and $t = 12,512$ seconds) differ markedly in spite of their close time proximity. This is true because the ESPOD vectors at these two time points were taken from independently reconstructed orbital segments separated by SPS1. The segment from which vectors at time $t = 12,480$ seconds were taken was reconstructed using tracking data between S-IVB-II cutoff and SPS1 ignition. The ESPOD segment containing time $t = 12,512$ seconds was generated from tracking data obtained during the intersecting ellipse orbit.

Table 3-12. Comparison of Recovered Accelerometer Biases

a) Segment 1

	<u>TRW (ft/sec²)</u>	<u>MSFC (ft/sec²)</u>
X	0.27×10^{-3}	0.14×10^{-3}
Y	0.12×10^{-3}	0.14×10^{-3}
Z	-0.36×10^{-3}	-0.51×10^{-3}

b) Segment 2

	<u>TRW (ft/sec²)</u>	<u>MSFC (ft/sec²)</u>
X	-0.12×10^{-5}	-0.20×10^{-4}
Y	0.25×10^{-3}	0.32×10^{-3}
Z	-0.75×10^{-3}	-0.79×10^{-3}

c) Two-revolution fit

	<u>TRW (ft/sec²)</u>	<u>MSFC (ft/sec²)</u>
X	0.13×10^{-3}	0.14×10^{-3}
Y	0.23×10^{-4}	0.27×10^{-3}
Z	-0.72×10^{-3}	-0.87×10^{-3}

Table 3-13. State Vector Comparisons in ECIG (GRR) Coordinates

Time, t, from GRR (sec)	\vec{P}, \vec{V} (ft, ft/sec)	ESPOD	Apollo G&N Reconstructed from GLOTAC Gravity and Initial Conditions	Apollo G&N Reconstructed from ESPOD State Vector Prior to S-IVB-II Ignition	Residuals (GN-ESPOD; GN Reconstructed from ESPOD State Vector)
11, 790 (Second S-IVB burn terminated at approximately t = 11, 788)	PX PY PZ VX VY VZ	19, 795, 495. 4 -3, 406, 605. 6 10, 597, 001. 0 14, 822. 41 26, 994. 23 -2, 029. 03	19, 796, 159. 2 -3, 405, 263. 6 10, 597, 408. 7 14, 819. 32 26, 994. 12 -2, 023. 31	19, 795, 692. 2 -3, 406, 437. 2 10, 597, 168. 7 14, 821. 57 26, 993. 45 -2, 026. 03	197. 0 168. 0 168. 0 -0. 8 -0. 8 3. 0
12, 480 (First service engine burn ignition occurred at approximately t = 12, 484)	PX PY PZ VX VY VZ	25, 108, 089. 9 14, 774, 332. 7 6, 996, 186. 7 1, 870. 81 24, 396. 65 -7, 345. 07	No GLOTAC coverage	25, 107, 902. 5 14, 774, 110. 0 6, 998, 417. 7 1, 871. 21 24, 395. 73 -7, 341. 74	-187. 0 -223. 0 2, 231. 0 0. 4 -0. 9 3. 3
12, 512 (First service engine burn shutdown occurred at approxi- mately t = 12, 504)	PX PY PZ VX VY VZ	25, 169, 024. 7 15, 552, 973. 0 6, 756, 312. 4 1, 598. 94 24, 307. 83 -7, 444. 81	No GLOTAC coverage	25, 163, 575. 0 15, 553, 615. 1 6, 761, 874. 1 1, 596. 55 24, 308. 34 -7, 442. 59	-5, 450. 0 642. 0 5, 561. 7 -2. 4 0. 5 2. 2

3.4 INTERSECTING ELLIPSE

Trajectory Analysis and Reconstruction

This section discusses and summarizes results obtained by reconstructing the AS-501 (Apollo 4) trajectory from Saturn-IVB/command service module (S-IVB/CSM) separation to entry (400,000 feet) using an orbit determination program (ESPOD) and low speed radar tracking data. Although Task A-50 was not responsible for the 10-minute period between the second S-IVB engine cutoff and S-IVB/CSM separation, the limited data between S-IVB/CSM separation and the first service propulsion system (SPS 1) engine cutoff made it necessary for the task to include the 10 minutes of free flight prior to S-IVB/CSM separation in its discussion. Therefore, the following subsection, Sequence of Events, will begin by describing the second S-IVB engine cutoff.

Sequence of Events

Following the two revolutions in the parking orbit, the second S-IVB burn injected the S-IVB/CSM configuration into an earth-intersecting coast ellipse. The second S-IVB engine cutoff occurred at 3 hours, 16 minutes, and 26.27 seconds from lift-off, where lift-off is referenced to range zero which occurred at 12 hours, 0 minute, and 1 second, GMT.

After 10 minutes of free flight, the Apollo guidance computer (AGC) received the S-IVB/CSM separation signal. Upon receipt of this signal, the reaction control system (RCS) jets were turned on. After 1.7 seconds of thrusting, the physical separation of the S-IVB/CSM occurred. The RCS jets continued thrusting for another 8.4 seconds, for a total time duration of 10.1 seconds. A total ΔV of 1.88 feet per second was added during this maneuver. The CSM then initiated a 26-second reorientation maneuver to obtain the proper ignition attitude for the first SPS burn. This maneuver was followed by a 64-second attitude-hold phase prior to SPS engine ignition.

At the end of the attitude-hold phase, 3 hours and 28.11 minutes after lift-off, the SPS engine ignition occurred. The burn lasted a total of 16 seconds with a ΔV of 213 feet per second. The result of the burn was

an earth-intersecting ellipse with eccentricity of 0.59 and a predicted apogee of 9778 nautical miles above the Fischer ellipsoid. A discussion of SPS 1 targeting parameters appears in the Maneuver Analysis and Targeting Parameter subsection.

Immediately following SPS 1 engine cutoff, 3 hours and 28.38 minutes after lift-off, the CSM initiated a 26-second reorientation maneuver to place the spacecraft into the desired attitude for solar cold soak.

Approximately 2 hours and 18.5 minutes after SPS 1 engine cutoff, the spacecraft reached an altitude of 9769 nautical miles at apogee. Then approximately 2 minutes after the AGC update had been received from the Carnarvon ground station, the AGC initiated a reorientation maneuver from the solar cold-soak attitude to the ignition attitude for the second SPS burn.

At 8 hours and 10.44 minutes from lift-off, the CSM RCS jets were turned on for a 28-second ullage burn. Immediately following ullage, SPS two-engine ignition occurred. The total time from SPS 1 engine cutoff to SPS 2 engine ignition was 4 hours and 42.54 minutes.

The duration of the SPS 2 burn was 280.6 seconds, during which a ΔV of 4829 feet per second was added. The SPS 2 engine cutoff occurred at 232.14 seconds before entry or 8 hours and 15.61 minutes from lift-off. The resulting inertial velocity and flight-path angle at SPS 2 engine cutoff was 35,115 feet per second and 107.64 degrees, respectively. A detailed description of SPS 2 targeting parameters is presented in the Maneuver Analysis and Targeting Parameter subsection.

Following SPS 2 engine cutoff, a reorientation maneuver was performed to obtain the desired attitude for command module/service module (CM/SM) separation. This attitude was maintained until CM/SM separation, which occurred at 8 hours and 18.04 minutes after lift-off. The separation maneuver was performed by firing four SM RCS thrusters to provide negative X-axis translation. The translation was to continue until the RCS propellant was depleted.

Approximately 5 seconds after the CM/SM separation, the guidance and navigation system was to begin orienting the command module to a predetermined attitude for atmospheric reentry.

At 8 hours and 19.326 minutes from lift-off, the spacecraft entered the earth's atmosphere (400,000 feet) in a hyperbolic orbit with an inertial velocity of 36,545 feet per second and a flight-path angle of 96.93 degrees.

Table 3-1 lists the major events along with the ground elapsed time and Greenwich mean time associated with each event.

Command Service Module Orbital Reconstruction

The command service module trajectory was reconstructed using low speed C-band radar tracking data and the TRW orbit determination program (ESPOD). Low speed unified S-band radar data were also used for the post-SPS 2 burn segment of the flight since C-band data did not exist for this segment of the mission. The earth-intersecting ellipse phase of the flight was also reconstructed using only S-band data, and also by using both the C-band and S-band data. These trajectories were then compared with the standard C-band trajectory to determine the quality of the S-band data and to measure the effects of using both radar data types in a fit. This comparison appears in the discussion of Segments 5 and 6.

The CSM orbital segment of the flight begins at S-IVB/CSM separation and ends at entry interface (400,000 feet). Because of the limited data situation between S-IVB/CSM separation and SPS 1 engine ignition, the 10 minutes of free flight preceding S-IVB/CSM separation were included in the analysis.

Data Processing

A magnetic tape containing low speed radar tracking data (C-band and S-band) was received and processed by the MATAG program which converted the data into a format compatible with ESPOD and generated a time-ordered master data tape. The EDG program edited the master data tape in the following manner:

- a) Deleted all data flagged invalid
- b) Deleted all data with elevations below 3 degrees

- c) Refracted all range and angle data using the mean monthly value of surface refractivity for each station
- d) Subtracted 123 feet from all IU range data
- e) Sorted data by object, i. e., S-IVB transponder, CSM transponder, and skin track
- f) Output radar observation cards

Table 3-14 summarizes the EDG output, which is radar observation cards. The table lists the station identification, the revolution, the date, the rise time (GMT), rise elevation (degrees), maximum elevation of the pass (degrees), set time (GMT), set elevation, and the total number of observations.

A summary of the data that were flagged invalid at the station appears in Appendix I.

Orbital Fit Discussion

Before each fit is discussed in detail, a few assumptions concerning these fits should be stated. First, it is assumed that all stations are in perfect time synchronization with one another unless otherwise noted. Second, it is assumed that all data are time tagged on the received pulse; thus, the light time correction retards the time tag of the data. Third, it is assumed that a 0.06-second timing bias added to all tracking data accounts for the difference between UTI and UTC for 9 November 1967.

A summary of station locations for both C-band and S-band stations can be found in Appendix H. Table 3-15 lists the values used by ESPOD to weight the radar tracking data from each station as a function of data type and radar type.

A summary of drag parameter values for various phases of the mission is listed in Table 3-16. The table lists the vehicle configuration, the time interval for which this particular value is valid, vehicle weight (pounds), vehicle cross sectional area (feet²), and the value of the drag parameter (feet²/slug).

Table 3-14. Summary of Radar Observations for the CSM Orbital Phase

Station	Revolution	Date (yr:mo:day)	Rise Time, GMT (hr:min:sec)	Rise* Elevation (deg)	Maximum* Elevation (deg)	Set Time, GMT (hr:min:sec)	Set* Elevation (deg)	Number of Observations
PATC	3	67:11:09	15:09:12	3.4	26.0	15:17:18	3.0	81
GBIC	3	67:11:09	15:09:48	2.9	19.8	15:15:12	9.8	55
MILS	3	67:11:09	15:09:48	7.0	28.0	15:14:00	11.1	43
BDQC	3	67:11:09	15:12:18	2.9	44.9	15:26:48	3.7	146
BDAC	3	67:11:09	15:12:30	4.1	44.9	15:27:36	2.8	88
ANTC	3	67:11:09	15:14:18	2.9	20.9	15:33:06	2.7	188
BDAS	3	67:11:09	15:15:12	3.0	32.8	15:20:42	13.3	53
CYIC	3	67:11:09	15:23:18	28.0	46.0	17:23:24	2.8	1128
ASCC	3	67:11:09	15:27:30	27.6	59.3	19:07:00	2.7	2267
ACNS	3	67:11:09	15:27:48	29.1	59.3	19:06:24	3.0	2221
CROC	3	67:11:09	17:18:36	2.7	39.4	20:12:18	2.8	1715
CROS	3	67:11:09	19:07:30	20.8	26.1	19:27:00	26.1	195
GWMS	3	67:11:09	20:13:42	14.9	30.4	20:18:00	22.8	42

* These elevations represent refracted elevations

Table 3-15. Radar Data Weighting (Coast Phase)

<u>Data Type</u>	<u>Type of Radar</u>	<u>Weighting</u>
R:A:E	FPQ-6	60 ft: 0.0258 deg: 0.0258 deg
R:A:E	TPQ-18 and FPS-16	90 ft: 0.0354 deg: 0.0354 deg
R:A:E	MPS-26	180 ft: 0.1720 deg: 0.1720 deg
R:X:Y	USB: 30-ft antenna 85-ft antenna	90 ft: 0.1375 deg: 0.1375 deg
Doppler (2 way)	USB: 30-ft antenna 85-ft antenna	0.2 cycles/sec

Table 3-16. Drag Summary

<u>Vehicle</u>	<u>Time Interval</u>		<u>Vehicle Weight (lb)</u>	<u>Vehicle Area (ft²)</u>	<u>Drag (ft²/slug)</u>
	<u>From (hr:min:sec)</u>	<u>To (hr:min:sec)</u>			
S-IVB/CSM	12:11:16	15:11:27	281,568	754.77	0.0858
S-IVB/CSM	15:16:27	15:26:29	122,000	754.77	0.1980
S-IVB	15:26:29	ENTRY	83,259	754.77	0.2901
CSM	15:26:29	15:28:07	51,787	129.35	0.0799
CSM	15:28:23	20:10:55	50,653	129.35	0.0817
CSM	20:15:36	20:18:03	24,872	129.35	0.1664
CM	20:18:03	ENTRY	11,960	129.35	0.3461

For purposes of determining a best estimated trajectory (BET), the CSM orbital segment of the flight was divided into four segments. In addition, two fits were made for the coast phase of the flight in order to evaluate the low speed S-band tracking data. Table 3-17 presents a summary of information pertinent to each of the above mentioned fits. For each fit the following are listed:

- The observation span of the data
- The data used in the fit
- The value of the drag parameter ($C_d A / 2m$)
- The solution vector
- The trajectory output

The 1962 COESA static atmosphere was used in all fits.

Segment 1 (Table 3-17) was reconstructed using all available C-band data between S-IVB cutoff and SPS 1 engine ignition.

The separation maneuver (15 hours, 26 minutes, and 27.52 seconds, GMT, to 15 hours, 26 minutes, and 37.61 seconds, GMT) was modeled by inputting a burn tape, generated from the Guidance and Navigation (G&N) tape, into the IGS ESPOD. Since the AGC was in the "average g mode" at this time, the telemetered data represent an accurate thrust profile at 2-second intervals. Because the AGC senses acceleration due to drag, it was not necessary to input the value for drag after separation (Table 3-16). Thus, only the value for drag ($0.198 \text{ ft}^2/\text{slug}$) before separation was input into ESPOD. The solution vector for the fit consisted of only the state vector, and convergence was achieved in two iterations.

The residual mean and RMS by station and type for Segment 1 is listed in Table 3-18 and indicates a reasonable fit. All quantities are defined as usual, and N is the number of data points for each observation type.

It should be noted that the residuals indicate a difference of about 100 to 150 feet between the S-IVB transponder data and the CSM transponder data (BDACO3 versus other data). Differences of this magnitude were also observed during the vent phase. The trajectory was generated

Table 3-17. Orbital Fit Summary (Coast Phase)

BET Segment	Date	Observation Span, GMT (hr:min)	Station/Pass, (Burn)	Drag (ft ² /slug)	Solution Vector	Trajectory Output
1	Nov. 9	15:16 - 15:28	PATCO3, ANTICO3, BDQCO3, BDACO3, and (Separation)	0.198	State vector	Event times
2	Nov. 9	15:29 - 19:30	ANTICO3, ASCCO3, and CROCO3	0.082	State vector	10-min intervals and event times.
3	Nov. 9	15:30 - 20:10	ANTICO3, ASCCO3, and CROCO3	0.082	State vector ASCC elevation and azimuth bias and CROC azimuth bias	10-min intervals and event times.
4	Nov. 9	20:15 - 20:17	GWMSO3	0.166 (before CM/SM separation) 0.346 (after CM/SM separation)	State vector	Event times
5	Nov. 9	15:29 - 20:07	ACNSO3, and CROSO3	0.082	State vector	NA
6	Nov. 9	15:29 - 20:10	ANTICO3, ASCCO3, ACNSO3, CROCO3, and CROSO3	0.082	State vector	NA

Table 3-18. Residual Mean and RMS by Station and Type for Segment 1

<u>Station/Pass</u>	<u>Transponder</u>	<u>Range</u>	<u>Azimuth</u>	<u>Elevation</u>	
BDACO3	S-IVB	-0.697985E 02	-0.128758E-01	0.449776E-02	Mean
		0.461880E 02	0.457317E-02	0.220438E-01	RMS
		36	36	36	N*
ANTCO3	CSM	-0.177881E 01	-0.832008E-02	0.637011E-01	Mean
		0.181946E 02	0.432167E-02	0.730249E-02	RMS
		113	114	114	N*
BDQCO3	CSM	0.828550E 01	-0.109482E-03	0.110107E-01	Mean
		0.212968E 02	0.425865E-02	0.673110E-02	RMS
		103	103	103	N*
PATCO3	CSM	0.590672E 02	0.152313E-02	-0.292679E-01	Mean
		0.177674E 02	0.351416E-02	0.646730E-02	RMS
		7	7	7	N*

*Number of data points

at all event times in this interval (Appendix B). The residual plots for this segment can be found in Appendix E. Pertinent comments will be made for each plot, if applicable.

Some difficulty was encountered reconstructing the trajectory for the coast phase from SPS 1 engine cutoff (15 hours, 28 minutes, and 23.6 seconds, GMT) to SPS 2 engine ignition (20 hours, 10 minutes, and 55.8 seconds, GMT) using low speed C-band radar tracking data. The problem was that at 15 hours and 30 minutes, GMT, the ASCCO3 range residuals suddenly dropped approximately 500 feet, and a strange range residual pattern was observed until 17 hours, 12 minutes, and 30 seconds, GMT. At this time, the range residuals jumped approximately 300 feet following a 30-second data drop. After the jump, the ASCCO3 range data were compatible with the CROCO3 range data. The ASCCO3 azimuth and elevation residuals during this same period appeared reasonable. The ACNSO3 (S-band) residuals were smooth during this interval, and subsequent fits of the S-band data indicated that the S-band data were good.

The RTCC also experienced problems during this period. A 300-yard range bias was observed between the ACNS USB data and the ASCC C-band data. It was assumed that the difficulty was with the USB station, and ACNS was asked to reacquire in range. This action seemed to reduce the bias by about 30 yards. At some later time, the range bias between ACNS and ASCC was observed to be approximately 50 yards. It now appears that the problem observed by the RTCC was caused by the ASCC radar rather than the ACNS radar.

Many attempts were made to reconstruct the coast phase in one segment without success. It was finally decided to reconstruct the coast phase trajectory in two segments to insure a good fit at both SPS 1 engine cutoff and SPS 2 engine ignition.

Segment 2 was reconstructed using ANTCO3 data, a small amount of ASCCO3 data after SPS 1 engine cutoff that were considered to be good, a small segment of ASCCO3 and CROCO3 data near apogee, and a small segment of CROCO3 near SPS2 engine ignition. A least-squares fit was made by regressing on the state vector. A drag value of 0.082 square foot per slug was used in the fit. In order to insure that the limited amount of

data used in the fit were representative, the residuals for all the C-band data were generated using the state vector from the above fit. The results indicated that the trajectory fit all the data until about 19 hours 50 minutes, GMT, or until about 20 minutes before SPS 2 engine ignition. It was decided that Segment 2 would represent the interval from SPS 1 engine cut-off (15 hours, 28 minutes, and 23.6 seconds, GMT) to 17 hours and 20 minutes, GMT. A vector comparison with Segment 3 revealed a total difference of 4325 feet in position and 0.88 foot per second in velocity. The residual mean and RMS by station and type for Segment 2 is listed in Table 3-19.

The trajectory was output at 10-minute intervals and at event times (Appendix B). The residual plots for this segment can be found in Appendix E where pertinent comments will be made for each plot, if applicable.

The trajectory for Segment 3 from 17 hours and 20 minutes, GMT, to SPS 2 engine ignition (20 hours, 10 minutes, and 55.8 seconds, GMT) was reconstructed using all the CROCO3 data; all the ASCCO3 data except for the interval from 15 hours and 30 minutes, GMT, to 17 hours, 12 minutes, and 30 seconds, GMT; and the ANTCO3 data. The CROC elevation data were weighted out because of a suspicious elevation residual trend. The problem was found to be caused by a refraction model error; i. e., the mean monthly value for surface refractivity at CRO for November is 329, while the value computed from temperature, pressure, and dew point for midnight November 10 (GMT) was 367. The solution vector consisted of the state vector, ASC azimuth and elevation biases, and CRO azimuth bias. Drag was modelled by inputting a 0.082-square foot per slug value for the drag parameter.

The residual mean and RMS by station and type for Segment 3 is listed in Table 3-20.

The trajectory was output at 10-minute intervals and at event times (Appendix B). The residual plots can be found in Appendix E where comments on each plot will be made, if applicable.

Systematic errors have an important effect on the residual patterns in Segments 2 and 3. By studying the residual patterns in azimuth and elevation for ASCCO3, noting crossover points, when the residuals change

Table 3-19. Residual Mean and RMS by Station and Type for Segment 2

<u>Station/Pass</u>	<u>Transponder</u>	<u>Range</u>	<u>Azimuth</u>	<u>Elevation</u>	
ASCCO3	CSM	-0.305062E 01	0.157170E-01	-0.894164E-02	Mean
		0.207316E 02	0.792031E-02	0.112129E-01	RMS
		30	30	30	N*
ANTCO3	CSM	0.173113E 01	-0.214716E-01	0.625807E-02	Mean
		0.424040E 02	0.510417E-02	0.181648E-01	RMS
		29	29	29	N*
CROCO3	CSM	0.197204E 01	-0.105836E-01	0.109805E-01	Mean
		0.200634E 02	0.412069E-02	0.507624E-02	RMS
		37	37	37	N*

* Number of data points

Table 3-20. Residual Mean and RMS by Station and Type for Segment 3

<u>Station/Pass</u>	<u>Transponder</u>	<u>Range</u>	<u>Azimuth</u>	<u>Elevation</u>	
ASCCO3	CSM	0.205335E 02	0.475128E-05	0.177274E-04	Mean
		0.330788E 02	0.382861E-02	0.786177E-02	RMS
		1117	1123	1123	N*
ANTCO3	CSM	-0.477373E 02	-0.882218E-02	0.795961E-02	Mean
		0.534282E 02	0.460502E-02	0.209231E-01	RMS
		32	32	32	N*
CROCO3	CSM	0.355774E 02	-0.582150E-04	0.113216E-01	Mean
		0.493979E 02	0.514189E-02	0.983461E-02	RMS
		1678	1688	1688	N*

*Number of data points

sign, and observing the geometry of the pass, one can isolate some apparent systematic errors. The azimuth residual pattern in Segment 2 has a crossover point (positive to negative) at approximately 15 hours and 35 minutes, GMT. The azimuth observable at this time is 19 degrees, which means that the apparent station location should lie on a line drawn through the assumed station location and oriented 19 degrees east of true North. The fact that the residuals change from positive to negative indicates the apparent location is south and west of the surveyed location on the 19-degree line. Using this new location, the elevation residuals should be negative throughout the pass because of the geometry, if a timing error is not present. However, the elevation residuals have a crossover point (negative to positive) at 15 hours and 42 minutes, GMT. This crossover point occurs 2 minutes after the maximum elevation of the pass is achieved. A positive timing bias in conjunction with the apparent station location error deduced from the azimuth residual pattern will yield a crossover point at some time after the occurrence of the maximum elevation of the pass. The positive timing error will also account for the minimum in the azimuth residuals at the time of the occurrence of maximum elevation, since the location error and the timing error are coupled in the same direction.

A similar analysis of the CROCO3 azimuth residual pattern does not reveal a crossover point. The geometry indicates that if a timing error or station location error existed, their effects would be most noticeable from 20 hours 0 minute, GMT, to 20 hours 10 minutes, GMT. But no crossover is observed, which leads one to conclude that the azimuth residual pattern can be removed by assuming a minus 0.009-degree bias in azimuth. This is a reasonable number considering the fact that the 1 σ uncertainty in azimuth bias for a FPQ-6 radar is 0.017 degree.

It was also found that a positive longitude error could account for the positive residual pattern. This was done by generating perfect data for the coast ellipse and perturbing the trajectory by a station location error or timing error. The elevation residuals for CROCO3 were not analyzed since they were degraded by a bad refraction correction as discussed above.

It is felt that the error discussed above is the result of the relative errors between Ascension and Carnarvon which are a function of pass geometry, refraction model, earth model, radar system errors, etc. Thus, the recovered values based on a least-squares fit of the low speed tracking data would not necessarily reflect a correction to station locations on the Fischer ellipsoid.

The trajectory for Segment 4 from SPS 2 engine cutoff (20 hours, 15 minutes, and 36.4 seconds, GMT) to entry interface (20 hours, 19 minutes, and 29.54 seconds, GMT) was reconstructed using the only radar tracking data available, viz., Guam S-band data. The valid data from Guam covered a 2.3-minute interval from 20 hours, 15 minutes, and 36 seconds, GMT, to 20 hours, 17 minutes, and 54 seconds, GMT. The fit used only the RXY data as the doppler data were found to be of poor quality.

A least-squares fit was made where the solution vector consisted of the state vector. A drag parameter value of 0.166 square foot per slug was used before CM/SM separation while a drag value of 0.346 square foot per slug was used after CM/SM separation. In spite of the limited data situation and the fact that Guam is a new station, the station summary shown in Table 3-21 indicates that a good fit was obtained.

Table 3-21. Residual Mean and RMS by Station and Type for Segment 4

<u>Station Identification</u>	<u>Transponder</u>	<u>Range</u>	<u>X-Angle</u>	<u>Y-Angle</u>	
GWMSO3	CSM	-0.772236E 00	0.368261E-03	0.498396E-02	Mean
		0.221189E 02	0.279870E-01	0.114703E-01	RMS
		24	24	24	N*

* Number of data points

The trajectory output was listed for SPS 2 engine cutoff, CM/SM separation and entry (Appendix B). The residual plots, found in Appendix E clearly show that the doppler data were of poor quality. Entry conditions are discussed in the subsection on Maneuver Analysis and Targeting.

Segment 5, which represents the coast phase of the flight, was reconstructed using all available low speed S-band tracking data.

Most of CROSO3 data did not come into the RTCC in real time; consequently, paper tapes had to be processed in order to obtain the data. This is the reason that the data do not appear in the residual plots. There is a preponderance (1915 versus 560) of ACNS data. A least-squares fit was made where the solution vector included only the state vector. A summary of pertinent information regarding the fit can be found in Table 3-17. A value of 0.082 square foot per slug was used for the drag parameter. The residual mean and RMS and station and type for Segment 5 is given in Table 3-22.

The S-band trajectory was generated in order to compare it with the C-band trajectory. The results are listed in Table 3-23 where the differences are defined to be S-band trajectory minus C-band trajectory.

First, it can be seen that the ACNSO3 data will have more leverage in the fit than the CROSO3 data. Thus, the orbit plane is not determined as good as in the Segment 2 or Segment 3 fit where the CROCO3 data had more of an influence on the fit. Second, the S-band fit reduced the positive hump in the doppler residual pattern after SPS 1 engine cutoff. (The geometry during this period after SPS 1 engine cutoff was more like near-earth orbit with its rapid angle changes.) The effect of reducing the hump in the S-band fit was to increase the velocity for the resulting trajectory. This velocity difference at SPS 1 engine cutoff will show up as a position difference at apogee, and then transfer back to a velocity difference at SPS 2 engine ignition. This pattern can be seen in the table. It can also be seen from the ACNSO3 plots (Appendix F) that as the range increases and the elevation decreases, the X, Y angles become noisier. If the switchover from ACNSO3 to CROSO3 occurred at some earlier time in the flight, then some of the noise on the X, Y angles would be eliminated. It should be noted that the discontinuity in the differences between 17 hours and 10 minutes and 17 hours and 30 minutes is due to the switch in BET segments.

In conclusion, the difference between the S-band trajectory and the C-band trajectory can be attributed to the ASCNO3 leverage on the S-band fit and the questionable doppler data after SPS 1 engine cutoff.

Table 3-23. S-band Trajectory Vector Comparisons

Comparison Time, GMT (hr:min:sec)	X (ft)	Y (ft)	Z (ft)	\dot{X} (ft/sec)	\dot{Y} (ft/sec)	\dot{Z} (ft/sec)	ΔR (ft)	ΔV (ft/sec)
15:28:23.6	-33	1,051	1,061	2.668	0.227	3.987	1,493	4.80
15:30:00	224	1,075	1,441	2.680	0.283	3.906	1,812	4.75
15:50:00	3,172	1,710	5,479	2.122	0.683	2.849	6,558	3.62
16:10:00	5,285	2,569	8,386	1.427	0.714	2.034	10,240	2.59
16:30:00	6,654	3,379	10,434	0.873	0.638	1.405	12,828	1.77
16:50:00	7,433	4,058	11,792	0.436	0.501	0.877	14,518	1.10
17:10:00	7,729	4,575	12,564	0.070	0.359	0.419	15,444	0.56
17:30:00	5,816	4,361	9,537	0.201	0.191	0.837	11,992	0.88
17:46:50.54	5,929	4,499	10,255	0.014	0.073	0.578	12,672	0.58
17:50:00	5,929	4,511	10,360	-0.018	0.054	0.527	12,761	0.53
18:10:00	5,775	4,495	10,792	-0.240	-0.095	0.190	13,039	0.32
18:30:00	5,351	4,285	10,797	-0.464	-0.257	-0.189	12,789	0.56
18:50:00	4,653	3,871	10,316	-0.702	-0.439	-0.627	11,960	1.04
19:10:00	3,656	3,222	9,257	-0.965	-0.651	-1.155	10,461	1.64
19:30:00	2,324	2,286	7,487	-1.266	-0.921	-1.826	8,166	2.41
19:50:00	616	958	4,780	-1.587	-1.332	-2.725	4,914	3.42
20:10:00	-1,279	-993	837	-1.319	-1.967	-3.808	1,823	4.48
20:10:55.8	-133	-1,088	612	-1.250	-1.976	-3.840	1,828	4.50

The residual plots for Segment 5 can be found in Appendix F. Pertinent comments will be made for each plot if applicable.

The ACNSO3 residual patterns for Segment 5 cannot be explained by any one systematic error. This was deduced by generating perfect data for a coast ellipse and then inputting a single systematic error (latitude error, longitude error, or timing error) and noting the residual patterns. From these runs, it is apparent that only a combination of errors will account for the patterns. First, it appears that the positive X-angle residual pattern is caused by a positive longitude bias. This bias has little effect on the Y-angle pattern. Second, the Y-angle pattern can best be explained by a positive latitude error. The latitude error also has little effect on the X-angle residual pattern. Third, it takes a positive timing error to account for the crossover in the range residual pattern at 18 hours and 8 minutes, GMT; the simple timing error produced crossover at 17 hours and 58 minutes, GMT, with perfect data.

The results of this comparison are compatible with the analysis of the ASCCO3 residual patterns for Segment 2; i. e., the actual location of the C-band station is south and west of the survey location, and there is a positive timing bias. This would be expected, since both stations are located on the same island.

Although the amount of CROSO3 data plotted is limited, it appears that there may be a positive longitude error. From Segment 3, it was suspected that CROCO3 azimuth residual pattern could best be explained by either an azimuth bias or a positive longitude error.

Segment 6 was reconstructed using all low speed C-band and S-band data except for the suspected ASCCO3 data from 15 hours and 30 minutes, GMT, to 17 hours, 12 minutes, and 30 seconds, GMT. A fit was made where the regression variables were position and velocity. A drag value of 0.082 square foot per slug was used in the fit. Table 3-24 gives the residual mean and RMS by station and type for Segment 6.

The C- and S-band trajectory was generated to compare with the C-band trajectory. The results are listed in Table 3-25 where the differences are defined to be C- and S-band trajectory minus C-band trajectory.

Table 3-24a. Residual Mean and RMS by Station and Type for Segment 6

<u>Station/Pass</u>	<u>Transponder</u>	<u>Range</u>	<u>Azimuth</u>	<u>Elevation</u>	
ANTCO3	CSM	0.940353E 02	-0.200969E-01	0.193197E-02	Mean
		0.208149E 02	0.555354E-02	0.112062E-01	RMS
		14	14	14	N*
ASCCO3	CSM	-0.119395E 03	0.147877E-01	-0.291858E-02	Mean
		0.173978E 03	0.393652E-02	0.802208E-02	RMS
		1137	1138	1138	N*
CROCO3	CSM	0.124999E 00	-0.122645E-01	0.127537E-01	Mean
		0.146077E 03	0.523258E-02	0.880359E-02	RMS
		1685	1686	1686	N*

* Number of data points

Table 3-24b. Residual Mean and RMS by Station and Type for Segment 6

<u>Station/Pass</u>	<u>Transponder</u>	<u>Range</u>	<u>X-Angle</u>	<u>Y-Angle</u>	<u>Doppler</u>	
ACNSO3	CSM	0.736297E 01	0.188400E-01	0.887848E-02	0.217236E-00	Mean
		0.160619E 03	0.695923E-02	0.652793E-02	0.459176E-00	RMS
		1913	1915	1915	1744	N*
CROSO3	CSM	0.104384E 03	-0.393853E-01	0.484062E-04	0.238200E-00	Mean
		0.334450E 02	0.354721E-02	0.343100E-02	0.106306E-00	RMS
		195	195	195	192	N*

* Number of data points

Table 3-25. C- and S-band Trajectory Vector Comparisons

Comparison Time, GMT (hr:min:sec)	X (ft)	Y (ft)	Z (ft)	\dot{X} (ft/sec)	\dot{Y} (ft/sec)	\dot{Z} (ft/sec)	ΔR (ft)	ΔV (ft/sec)
15:28:23.6	666	635	1,154	1.135	0.035	1.555	1,476	1.93
15:30:00	774	639	1,300	1.112	0.069	1.485	1,643	1.85
15:50:00	1,849	860	2,662	0.677	0.231	0.853	3,354	1.11
16:10:00	2,449	1,140	3,448	0.347	0.217	0.486	4,380	0.64
16:30:00	2,726	1,367	3,869	0.125	0.161	0.232	4,926	0.31
16:50:00	2,781	1,523	4,025	-0.027	0.100	0.038	5,124	0.11
17:10:00	2,674	1,605	3,973	-0.145	0.040	-0.120	5,051	0.19
17:30:00	640	1,064	471	0.210	-0.035	0.584	1,328	0.62
17:46:50.54	851	1,017	1,054	0.199	-0.065	0.561	1,695	0.60
17:50:00	890	1,005	1,159	0.199	-0.067	0.555	1,773	0.59
18:10:00	1,113	913	1,794	0.173	-0.100	0.502	2,300	0.54
18:30:00	1,299	774	2,352	0.136	-0.129	0.422	2,796	0.46
18:50:00	1,430	602	2,797	0.077	-0.160	0.312	3,199	0.36
19:10:00	1,466	390	3,083	-0.024	-0.196	0.158	3,436	0.25
19:30:00	1,344	120	3,147	-0.202	-0.265	-0.067	3,424	0.34
19:50:00	923	-311	2,867	-0.536	-0.507	-0.436	3,028	0.86
20:10:00	56	-1,442	1,813	0.729	-1.674	-1.348	2,396	2.27
20:10:55.8	33	-1,522	1,824	0.687	-1.751	-1.434	2,376	2.37

Table 3-25 reveals much smaller differences between the C- and S-band trajectory and the C-band trajectory than the differences in the S-band trajectory and the C-band trajectory. This can be attributed to the effect of the C-band data in the fit. The jump in the position between 17 hours and 10 minutes, GMT, and 17 hours and 30 minutes, GMT, is due to the switch in BET segments. It can be concluded from the difference listed in the table that a good trajectory was reconstructed using both C-band and S-band data.

The residual plots for Segment 6 can be found in Appendix G. Pertinent comments will be made on each plot, if applicable.

The residual patterns for Segment 6 are essentially the same as for Segment 5; therefore, the same systematic errors would be recovered for Segment 6.

Before this section is concluded, it should be stressed that comments pertinent to data anomalies and trackers will be made with the plots. It is felt that this is a more effective way of presenting this information.

Maneuver and Targeting Analysis

First, it should be mentioned that many attempts were made to reconstruct the maneuvers using the low-speed C-band tracking data, telemetry information in the form of an acceleration burn tape, and IGS ESPOD. However, the lack of a priori knowledge of the guidance errors and the problems in the data prevented a good reconstruction of the SPS 1 and SPS 2 burns. The data problems are listed as follows:

- Bad ASCCO3 segment from 15 hours and 30 minutes, GMT, to 17 hours, 12 minutes, and 30 seconds, GMT
- Refraction problem at CROCO3
- Lack of low speed C-band tracking data after SPS 2

In order to give the reader some idea of the magnitude of the burns, the following information is tabulated. Table 3-26 lists the maneuver, the time of initiation of the maneuver (GMT), source of the information, the duration of the maneuver in seconds (Δt), the component velocities in

Table 3-26. Maneuver Summary

<u>Maneuver</u>	<u>Time of Initiation, GMT (hr:min:sec)</u>	<u>Source</u>	<u>Δt (sec)</u>	<u>ΔV_x (ft/sec)</u>	<u>ΔV_y (ft/sec)</u>	<u>ΔV_z (ft/sec)</u>	<u>ΔV (ft/sec)</u>
S-IVB/CSM Separation	15:26:27.52	G&N	10.09	-0.614	-0.597	1.674	1.88
SPS 1 Burn	15:28:07.60	G&N	16.00	-114.899	-22.205	173.318	213.29
SPS 2 Ullage*	20:10:27.36	G&N	28.44	-0.554	-0.857	6.006	6.09
SPS 2 Burn	20:10:55.80	G&N	280.60	-264.461	-291.362	4813.164	4829.22

* Approximate values

guidance platform coordinates, and the total velocity. It should be noted that the listed velocities have not been corrected for guidance errors.

The targeting parameters for the SPS 1 burn were a semilatus rectum of 32,833,369 feet and an eccentricity of 0.5913. In the event of the failure of SPS 2, entry (400,000 feet) would have occurred at 20 hours, 20 minutes, and 29.69 seconds with an inertial velocity of 32,281 feet per second, a flight-path angle of 100.29 degrees, and a location of 22.06° north latitude and 152.74° east longitude. These values are based on the Segment 3 reconstructed trajectory.

The eccentricity of the orbit resulting from the SPS 2 burn was 1.022, i. e., a hyperbolic reentry orbit. The entry occurred at 20 hours, 19 minutes, and 29.54 seconds with an inertial velocity of 36,545 feet per second and a flight-path angle of 96.93 degrees. These values are based on the Segment 6 reconstructed trajectory.

3.5 REENTRY

Using the error set described in Table 3-3, the G&N trajectory was reconstructed from time $t = 29,425.75$ seconds to splashdown. This interval includes all events from the second service propulsion system burn through splashdown. The reconstructed trajectory was initialized on the ESPOD state vector, thereby forcing initial agreement with the BET. The altitude time history of this reconstructed trajectory is presented graphically from the time of drogue chute deployment ($t = 30,678$ seconds) through splashdown. The coordinate set chosen for presentation is "local, earth surface fixed" so that the origin of coordinates coincides with the spacecraft recovery point as determined by the recovery ship. This point is the recovery ship's most accurate estimate of the splash point. The local coordinate axes are oriented as follows: X (local) is directed east; Y (local) is directed north; and Z (local) is directed "up", normal to the tangent plane of the Fischer Ellipsoid at the assumed point of impact. The geodetic coordinates of the origin are geodetic latitude = 30.106° N and geodetic longitude = 187.463° E.

Information on the actual reentry trajectory is available from several sources. The impact point coordinates (discussed above) were estimated by the recovery ship. The times of drogue and main chute deployment were determined from baroswitch closure times reflected in the telemetry data. The altitude intervals in which these events most probably occurred were determined from baroswitch presettings and estimates of the equipment and atmospheric pressure profile uncertainties. A wind velocity of 20 knots at 90 degrees, measured by the recovery ship, affords an east (local X) velocity estimate of approximately -34 feet per second. Additionally, experience with the Apollo command module descent rate on the main chute leads to an expected vertical velocity (local Z) in the range from -28 to -30 feet per second. Finally, at times subsequent to splashdown, the total position and velocity of the spacecraft were zero, by definition. Comparisons of these values with those obtained from the reconstructed G&N trajectory are presented in the following table.

	<u>Known Constraints</u>	<u>Reconstructed G&N</u>
Drogue Deployment (t = 30,678.0 sec)	PZ (Altitude): 22,700 - 26,000 ft	24,084 ft
Main Chute Deployment (t = 30,725.4 sec)	PZ (Altitude): 10,200 - 10,750 ft	11,020 ft
Pre-splash (t = 31,023.75 sec, immediately prior to impact; impact occurred at approxi- mately 31,035 sec)	PX: 0. ft	7,913 ft
	PY: 0. ft	-2,818 ft
	PZ: 0. ft	-370 ft
	VX: -34 ft/sec	-27.9 ft/sec
	VY: 0 ft/sec	9.4 ft/sec
	VZ: -28 to -30 ft/sec	-29.0 ft/sec

There are no significant differences between any of these reconstructed trajectory parameters and the values of their corresponding constraints. During the iterative procedure used to fit guidance data to external trajectory constraints, it was interesting to note the behavior of the impact state vector. Naturally, PZ and VZ must simultaneously match their reference values since these are accurately known constraints. Surface wind velocity and impact latitude-longitude, however, have large uncertainties^{*} and are independently derived. The analysis procedure demonstrated that whenever the wind constraint was satisfied, the reconstructed impact position was very close to the recovery ship estimate, and vice versa. This gives the analyst confidence in the reliability of the reference data, and in the accuracy of the reconstructed trajectory.

At the time of delivery of the A-50 45 Day BET, a detailed IMU error evaluation had not been completed because of difficulties in determining which of the several reference trajectories received for the ascent phase best represented the actual mission. Estimates of the most significant errors had been made. With this intermediate IMU evaluation, and with the knowledge that large platform misalignments existed at the time of the entry burn, it was possible to reconstruct the entry trajectory with

^{*}Numerical values of these uncertainties are not available.

Table 3 -27. Comparison of the 45 Day BET and Trajectory Derived from the Final IMU Accuracy Evaluation

Event (to nearest 2 sec)	Time from GRR (sec)	Geodetic Altitude (ft)	Relative Velocity (ft/sec)	Latitude (° North)	Longitude (° East)	
Entry Interface	29, 967. 75	405, 117 405, 226	35, 215. 9 35, 215. 5	21. 835 21. 837	152. 423 152. 421	45 Day BET Final Evaluation
$\dot{R} = 0$	30, 047. 75	182, 427 182, 522	30, 411. 4 30, 412. 0	24. 490 24. 493	159. 968 159, 967	45 Day BET Final Evaluation
$\dot{R} = 0$	30, 231. 75	241, 565 241, 506	21, 390. 2 21, 391. 4	27. 880 27. 878	172. 536 172. 537	45 Day BET Final Evaluation
Drogue Chute	30, 677. 75	24, 413 24, 151	450. 9 451. 7	30. 090 30. 077	187. 500 187. 508	45 Day BET Final Evaluation
Impact	31, 023. 75	-261 -370	43. 9 41. 3	30. 106 30. 098	187. 476 187. 489	45 Day BET Final Evaluation

a fair degree of confidence. The final IMU evaluation confirms this reconstruction and no revision of the 45 Day BET will be issued. A comparison of the BET entry trajectory with that derived from the final IMU errors (Table 3-3) is given in Table 3-27 at several times of interest.

Figure 3-8 illustrates the altitude-time history of the reconstructed entry trajectory.

3.6 RTCC ORBIT DETERMINATION EVALUATION

The state vectors obtained in real time by the RTCC for the AS-501 mission were compared with the Task A-50 best estimate of the trajectory (BET) at RTCC anchor time from insertion (12 hours, 11 minutes, 16.64 seconds, GMT) to entry (20 hours, 19 minutes, 29.54 seconds, GMT). The purpose of making these comparisons is to aid the RTCC in evaluating fit procedures for this and subsequent Apollo missions.

The comparisons are listed with comments for each vector comparison. A set of special vectors of prime interest to the RTCC will also be discussed. As previously noted, a time bias was added to the time tag of the low speed tracking data to account for the difference between UT1 and UTC. The real time orbit determination program does not account for the difference between UT1 and UTC. Thus, the RTCC trajectory is out of phase with the resultant post-flight trajectory. These differences are reflected in the state vector comparisons.

Table 3-28 lists in detail the data received and processed by the RTCC. The maximum elevation of the pass (E_{MAX}), anchor vector time (GMT), number of valid points, and an indication that the data were either accepted or rejected (A/R) is tabulated. An "S" in the accept/reject column denotes an accepted single station solution. The batch number is simply a numbering system used by the RTCC and has no special significance. The MSC memorandum on the RTCC Mission Data Summary was the source of Table 3-28.

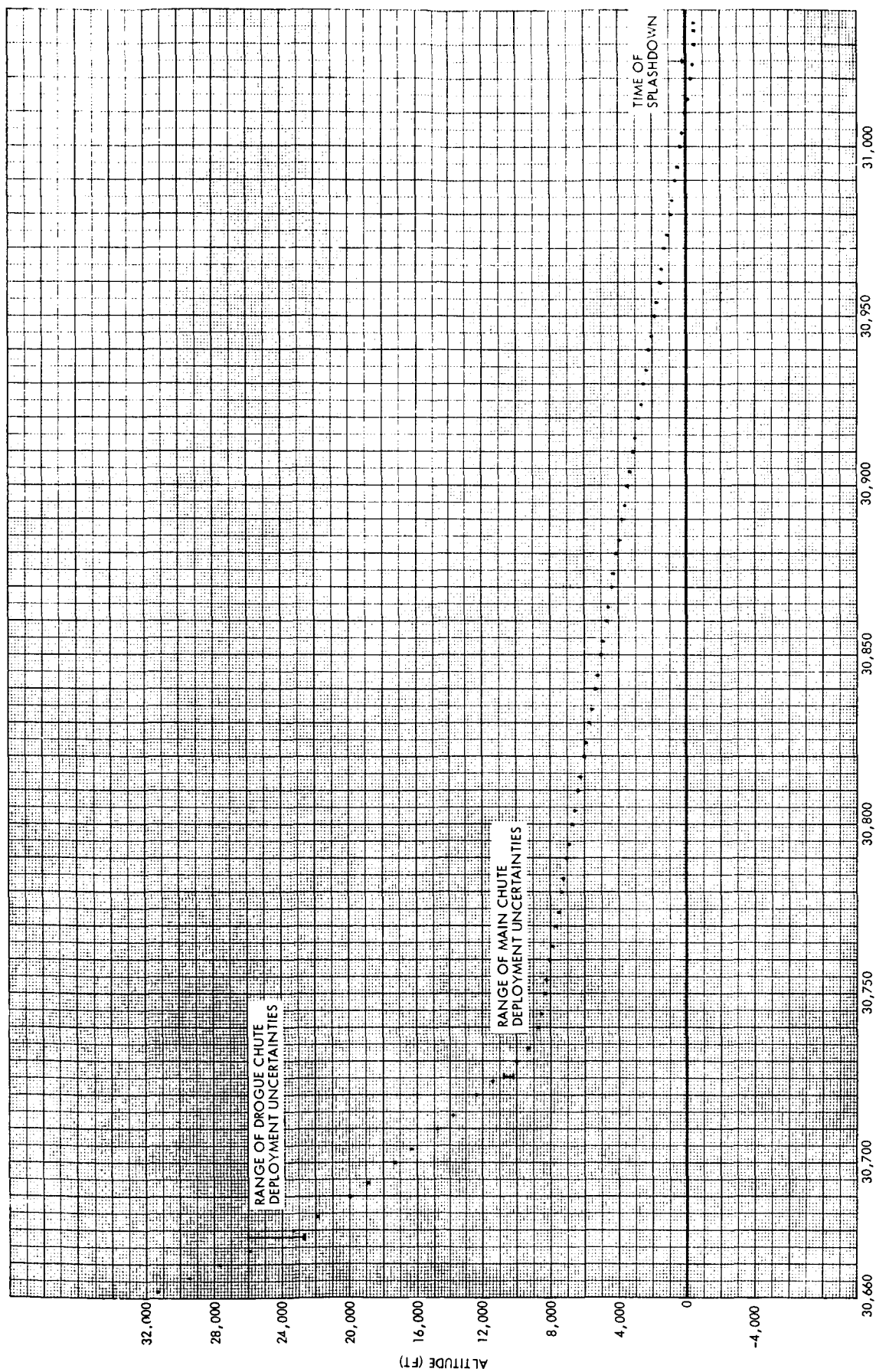


Figure 3-8. Altitude-Time History

Table 3-28. RTCC Summary of Radar Data for AS-501

<u>Code</u>	<u>Batch</u>	<u>Anchor Time (hr:min:sec)</u>	<u>N</u>	<u>EMAX (deg)</u>	<u>A/R</u>
BDAC	04	12:11:24	7	6	S
BDAS	08	12:11:24	6	6	A
VANC	09	12:11:24	42	57	R
VANS	10	12:12:36	33	55	R
CROC	11	12:53:00	44	8	A
CROS	13	12:53:00	36	9	A
WOMC	12	13:00:24	6	76	R
GYMS	17	13:29:06	16	26	R
WHSC	18	13:30:30	53	20	A
GDSS	19	13:30:36	18	5	R
MLAC	21	13:35:48	26	21	A
MILS	24	13:38:06	16	24	R
GBIC	22	13:36:30	52	14	A
PATC	23	13:37:12	43	21	A
BDAC	29	13:39:12	36	90	A
BDQC	25	13:39:24	54	83	A
BDAS	31	13:41:24	28	83	A
VANS	26	13:45:06	33	37	R
VANC	27	13:46:30	26	37	R
CYIC	30	13:51:00	37	6	A
CROC	32	14:26:12	51	12	A
CROS	33	14:26:18	41	12	R
HAWC	34	14:51:36	47	10	R
CALC	35	15:00:30	45	20	A
GDSS	46	15:02:12	38	20	R
WHSC	47	15:05:18	10	86	A
BDQC	48	15:17:06	32	27	S
ANTC	50	15:17:06	52	21	A
VANC	53	15:17:06	71	47	R
BDQC	58	15:20:18	62	14	A
ANTC	59	15:22:18	42	15	A

Table 3-28. RTCC Summary of Radar Data for AS-501 (Continued)

<u>Code</u>	<u>Batch</u>	<u>Anchor Time (hr:min:sec)</u>	<u>N</u>	<u>EMAX (deg)</u>	<u>A/R</u>
ANTC	60	15:26:42	15	9	S
ANTC	61	15:28:36	18	7	S
VANC	64	15:29:18	58	20	R
ASCC	66	15:29:18	62	51	A
ACNS	67	15:29:18	68	57	A
ANTC	57	15:30:24	28	5	A
ASCC	62	15:35:42	80	59	A
VANC	63	15:35:48	80	12	R
ACNS	65	15:36:06	80	59	R
ASCC	68	15:44:06	80	58	A
ACNS	69	15:44:06	80	58	A
VANC	70	15:44:48	34	5	R
ASCC	71	15:51:42	80	53	A
ACNS	72	15:52:06	80	53	A
ASCC	74	15:59:42	80	49	A
ACNS	75	16:00:16	80	48	A
ASCC	76	16:07:42	80	45	A
ACNS	77	16:08:12	80	45	A
ASCC	78	16:15:54	77	42	A
ACNS	79	16:16:36	58	42	A
ASCC	86	16:44:06	59	34	A
ACNS	88	16:57:42	80	32	A
ACNS	89	17:06:42	80	30	A
ASCC	90	17:07:42	80	30	A
ACNS	91	17:13:42	80	29	A
ASCC	92	17:16:36	129	29	A
CROC	93	17:18:56	200	5	A
ACNS	94	17:23:18	159	28	A
ASCC	95	17:29:48	159	27	A

Table 3-28. RTCC Summary of Radar Data for AS-501 (Continued)

<u>Code</u>	<u>Batch</u>	<u>Anchor Time (hr:min:sec)</u>	<u>N</u>	<u>EMAX (deg)</u>	<u>A/R</u>
CROC	96	17:34:00	159	8	A
ACNS	97	17:39:12	119	25	A
ASCC	98	17:45:42	119	24	A
CROC	99	17:49:54	80	11	A
ACNS	100	17:56:24	80	22	A
ASCC	101	18:06:18	230	20	A
CROC	102	18:12:36	230	15	A
ACNS	103	18:20:24	80	18	A
ASCC	104	18:30:06	230	15	A
CROC	105	18:36:24	212	19	A
ACNS	106	18:44:12	210	11	A
ASCC	107	18:54:36	168	8	A
CROC	108	18:59:24	187	23	A
CROC	109	19:17:36	80	26	A
CROC	110	19:28:36	80	28	A
CROC	111	19:33:36	80	32	A
CROC	112	19:41:36	80	36	A
CROC	113	19:49:36	80	39	A
CROC	114	19:57:54	80	39	A
CROC	117	02:08:00	45	31	A
GWMS	118	20:15:30	26	30	S

Notes: Data from TANC was received but not processed by the RTCC.
CROS data during the third revolution was received post mission.

2ND BURN SENSED COMPARISONS/GN-GLOTRAC

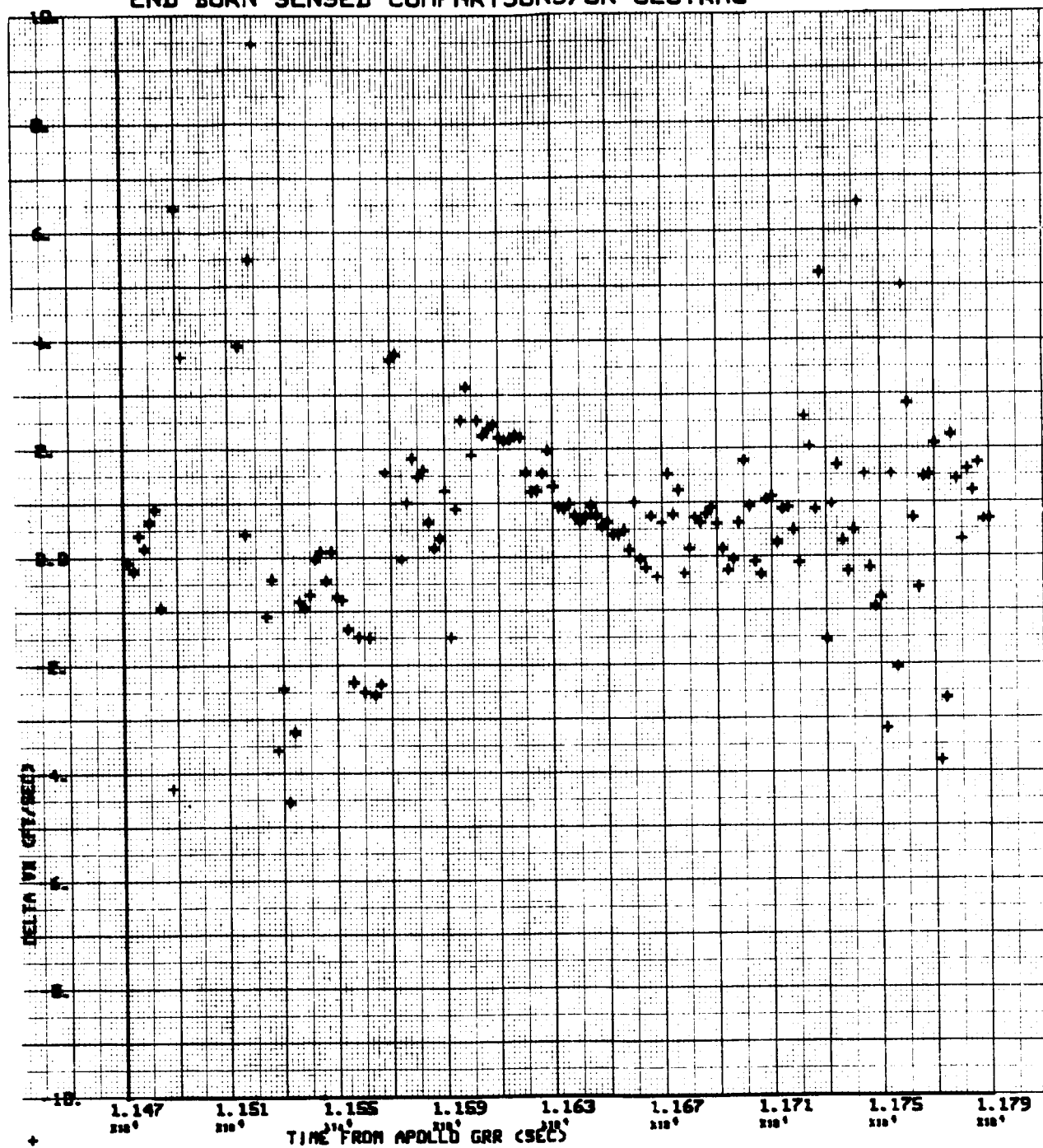


Figure 3-9. 2nd Burn Sensed Comparisons/GN-GLOTRAC; Delta VX

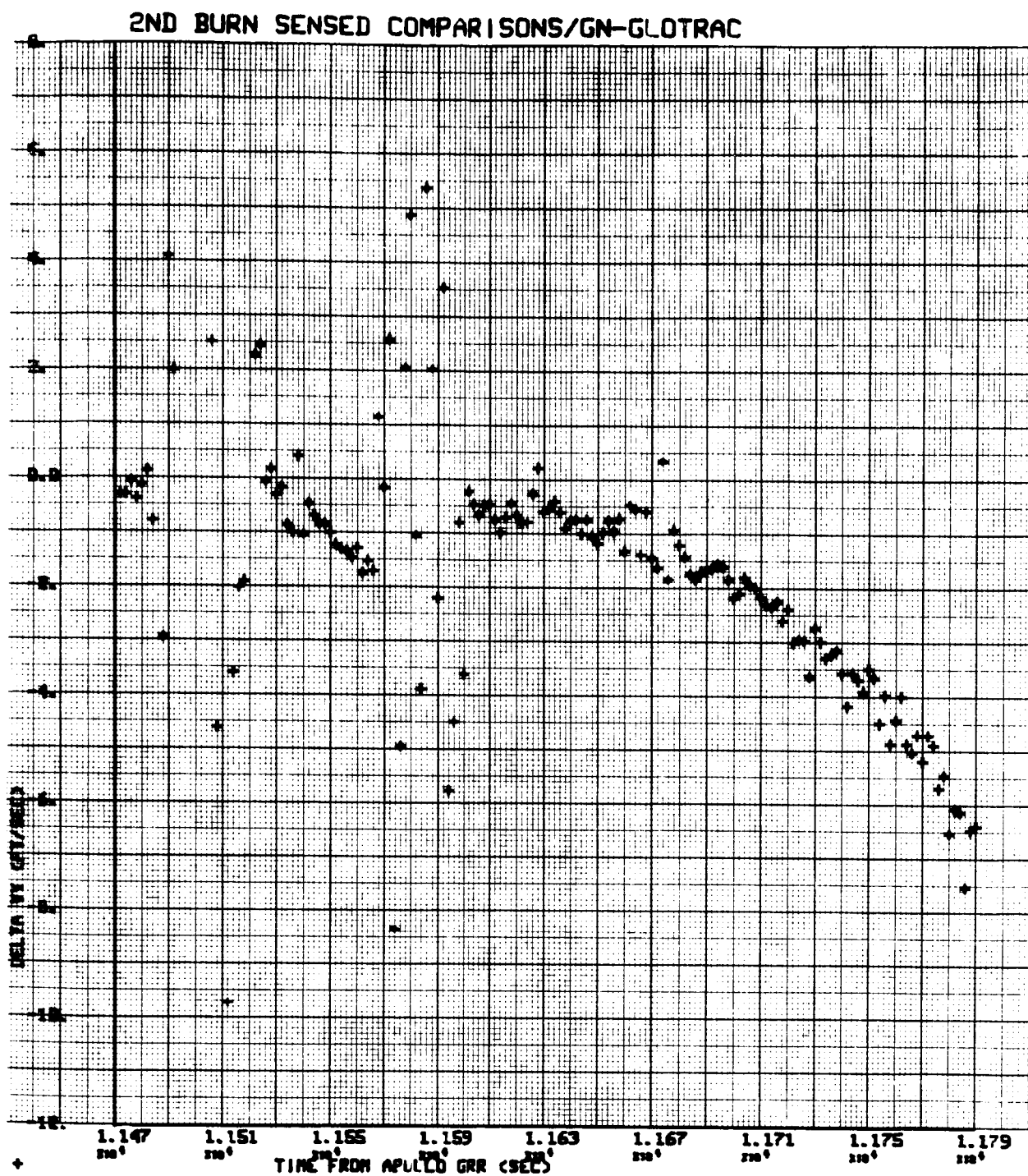


Figure 3-10. 2nd Burn Sensed Comparisons/GN-GLOTRAC; Delta VY

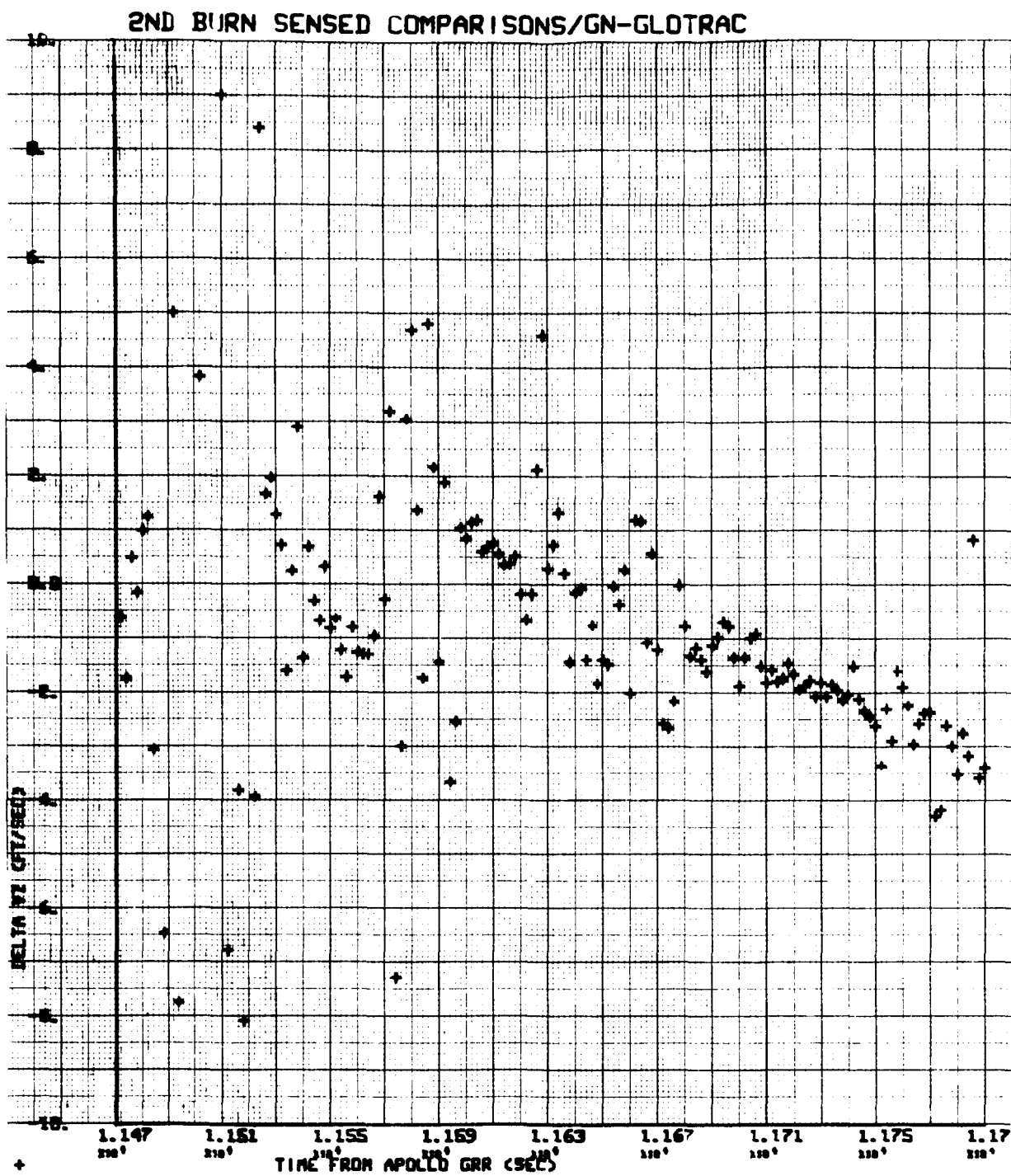


Figure 3-11. 2nd Burn Sensed Comparisons/GN-GLOTRAC; Delta VZ

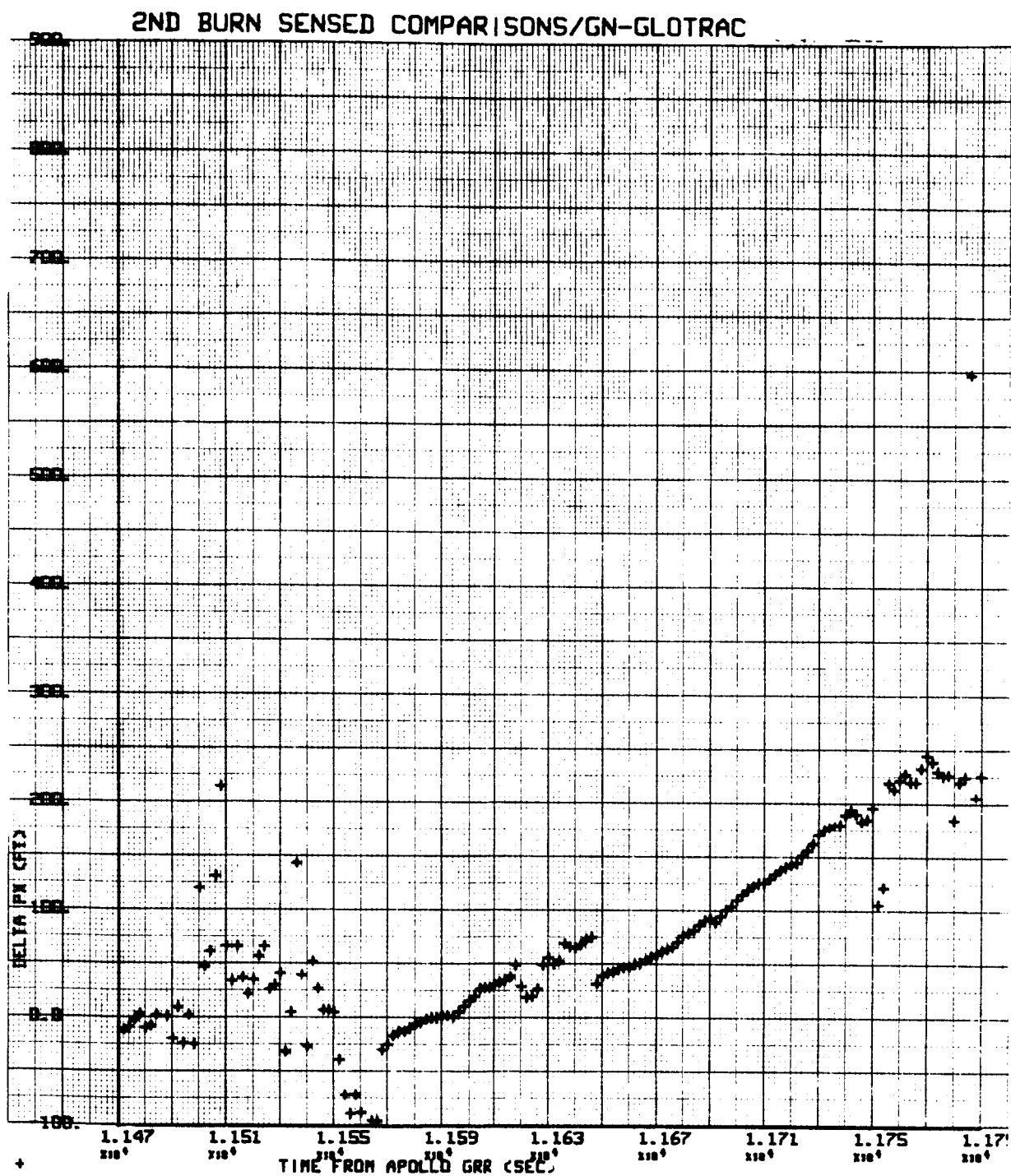


Figure 3-12. 2nd Burn Sensed Comparisons/GN-GLOTRAC; Delta PX

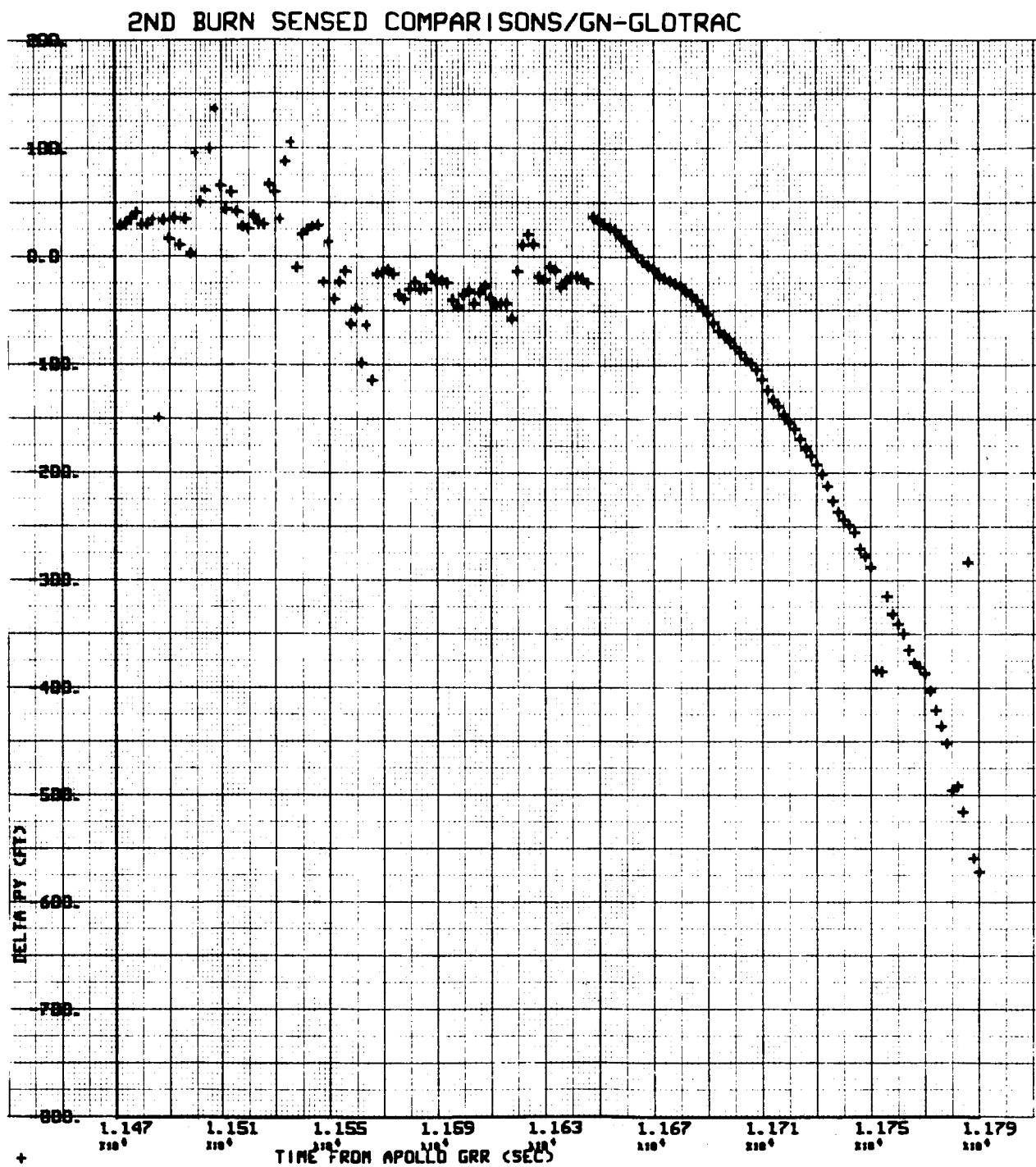


Figure 3-13. 2nd Burn Sensed Comparisons/GN-GLOTRAC; Delta PY

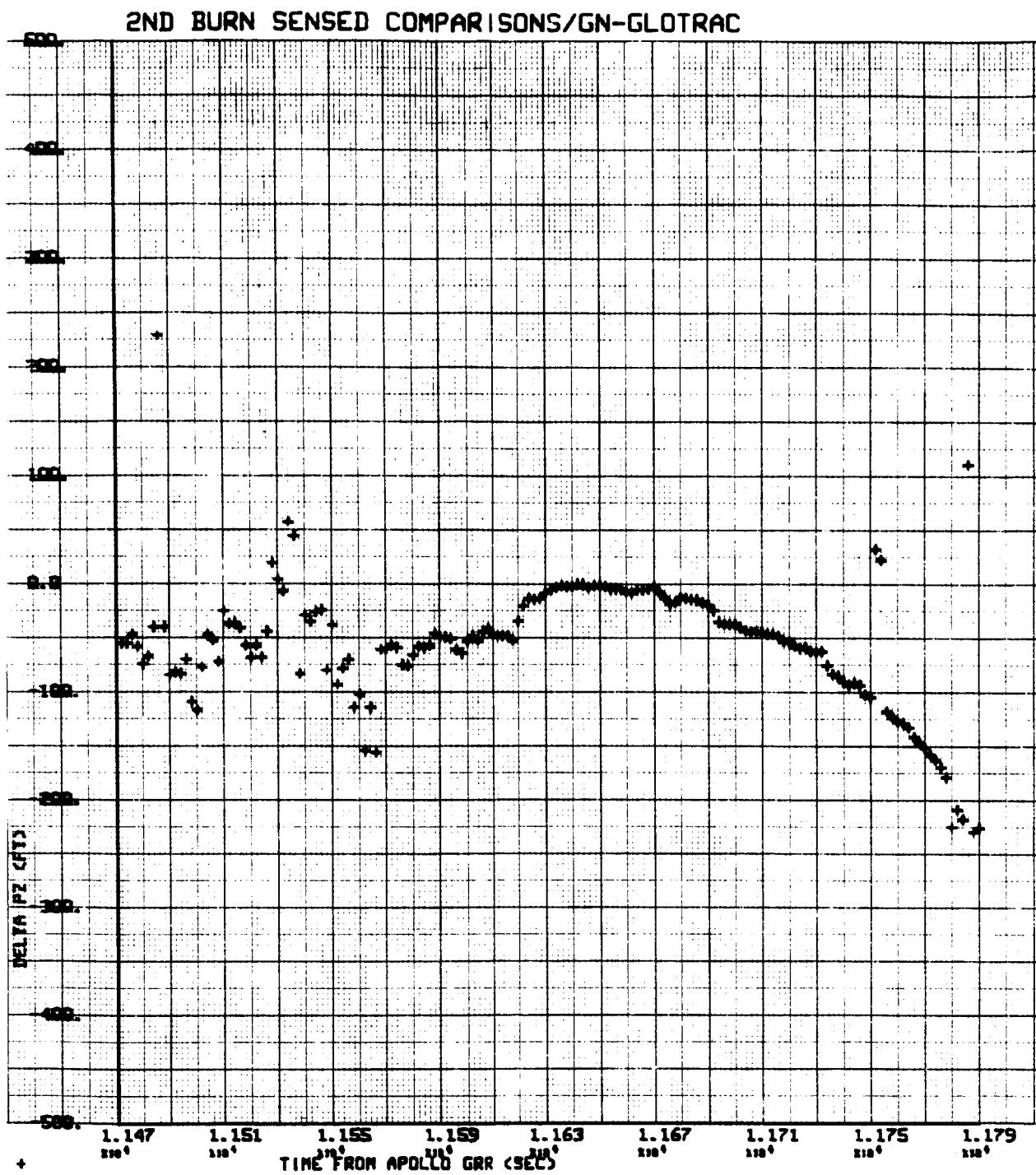


Figure 3-14. 2nd Burn Sensed Comparisons/GN-GLOTRAC; Delta PZ

RTCC Comparison

The comparisons made for the parking orbit will be discussed first. Since TRW Task A-50 reconstructed the trajectory in order to evaluate the MSFC vent polynomial technique, the task was asked to make RTCC comparisons for this segment of the flight.

A summary of these comparisons is listed in Table 3-29. The table lists the data used in the fit to obtain the RTCC vector, the RTCC batch number, the RTCC anchor time (GMT), the maximum elevation of the pass (E_{MAX}), the BET segment number, the total difference in position, and the total difference in velocity.

It can be seen that differences in position were about the same throughout the parking orbit. The velocity differences were not good until the first pass over the United States. When the data situation was good, the RTCC did a good job determining the orbit.

Table 3-29. RTCC Comparison Summary for the Parking Orbit

<u>Station</u>	<u>Batch</u>	<u>Anchor Time (hr:min:sec)</u>	<u>E_{MAX} (deg)</u>	<u>BET</u>	<u>ΔR(ft)</u>	<u>ΔV (ft/sec)</u>
BDAC	04	12:11:24	6	1	1687	19.54
BDAS	08	12:11:24	6	1	1720	13.91
CROC	11	12:53:00	8	1	1817	3.27
CROS	13	12:53:00	9	1	1388	5.92
WHSC	18	13:30:30	20	1	1396	2.51
MLAC	21	13:35:48	21	1	1603	1.34
BDQC	25	13:39:24	83	2	1445	1.03
BDAS	31	13:41:24	83	2	1433	0.99
CYIC	30	13:51:00	6	2	1653	0.45
CROC	32	14:26:12	12	2	3031	1.84
WHSC	47	15:05:18	86	2	1942	0.22

The summary of the comparisons from the second S-IVB engine cutoff to entry is listed in Table 3-30. All quantities are defined the same as in Table 3-29. The largest differences which appear in Table 3-30 are from ANTC61 to ACNS103. A part of these large differences can be explained by the following:

- The RTCC was using data from ASCC03 and ACNS03 until about 17 hours, 20 minutes, GMT. Therefore, the geometry was not good until Carnarvon tracked.
- The elevation at CROC03 did not get above 10 degrees until after 18 hours, GMT. The refraction problem at Carnarvon has a significant effect on the trajectory. The elevation data from CROC03 were weighted out of all the postflight fits.
- The ASCC03 data from 15 hours, 30 minutes, GMT, to 17 hours, 12 minutes, 30 seconds, GMT, were deleted from the postflight fits due to their strange behavior. (Appendix E presents the residual plots). The RTCC incorporated the ASCC03 data into their fits.

Special Comparisons

The summary of special comparisons can be found in Table 3-31. The vectors are time ordered according to RTCC anchor time, and the total difference in position and velocity is listed.

Table 3-30. RTCC Comparison Summary from Second S-IVB
Engine Ignition to Entry

Station	Batch	Anchor Time (hr:min:sec)	E _{MAX} (deg)	BET	ΔR (ft)	ΔV (ft/sec)
BDQC	48	15:17:06	27	3	2,026	2.16
ANTC	50	15:17:06	21	3	1,602	2.17
BDQC	58	15:20:18	14	3	1,936	3.19
ANTC	59	15:22:18	15	3	2,202	3.91
ANTC	61	15:28:36	7	4	10,453	80.83
ASCC	66	15:29:18	51	4	7,014	7.33
ACNS	67	15:29:18	57	4	6,742	5.35
ACNS	65	15:36:06	59	4	7,858	12.29
ASCC	68	15:43:42	58	4	8,348	7.02
ASCC	74	15:59:42	49	4	12,936	8.21
ACNS	75	16:00:06	48	4	13,300	7.91
ASCC	86	16:44:06	34	4	19,253	4.20
ACNS	88	16:57:42	32	4	22,405	3.88
ACNS	91	17:13:42	29	4	21,446	3.15
ASCC	92	17:16:36	29	4	18,850	2.82
ACNS	97	17:39:12	25	5	11,349	2.00
ASCC	98	17:45:42	24	5	11,177	2.08
ACNS	100	17:56:24	22	5	8,943	2.30
ASCC	101	18:06:18	20	5	7,682	2.42
CROC	102	18:12:36	15	5	7,015	2.50
ACNS	103	18:20:24	18	5	5,747	2.58
ACNS	106	18:44:12	11	5	2,842	2.81
ASCC	107	18:54:36	8	5	1,145	2.85
CROC	108	18:58:24	23	5	2,002	2.97
CROC	110	19:25:36	28	5	1,792	3.12
CROC	112	19:41:36	36	5	3,379	2.45
CROC	113	19:49:36	39	5	3,510	1.67
CROC	114	19:57:54	39	5	2,674	1.01
CROC	117	20:06:00	31	5	2,208	1.18
GWMS	118	20:15:30	30	6	2,621	5.35

Table 3-31. RTCC Comparison Summary for Special Vectors

<u>Vector Description</u>	<u>Anchor Time (hr:min:sec)</u>	<u>ΔR (ft)</u>	<u>ΔV (ft/sec)</u>
AGC Insertion Vector	12:11:21.57	17,922	50.10
IP Raw Insertion Vector	12:11:22.25	4,598	19.05
USB Insertion Vector	12:11:22.25	2,664	85.43
IU Insertion Vector	12:11:22.3	21,888	17.26
BDQC 025 Vector Used to Build AGC Navigation Update Prior to J2	13:39:24.0	1,515	1.09
WHSC 047 Best RTCC Vector Prior to TLI	15:05:18.0	1,942	0.22
AGC High Speed Cutoff Vector Following TLI	15:16:45.7	46,609	44.91
IP RAW High Speed Cutoff Vector Following TLI	15:18:08.7	8,932	15.04
ANTC 059 Best RTCC Vector Prior to SPS-1	15:22:18.0	2,202	3.91
IP RAW High Speed Cutoff Vector Following SPS-1	15:29:53.8	13,859	10.04
ACNS 079 Vector Used to Build AGC Navigation Update Prior to SPS-2	16:16:36.0	15,219	5.57
CROC 117 Best RTCC Vector Prior to SPS-2	20:06:00.0	2,208	1.18
AGC High Speed Cutoff Vector Following SPS-2	20:15:44.32	38,805	92.64
GWMS High Speed Cutoff Vector Following SPS-2	20:16:28.50	2,662	39.42

The output of the RTCC Compare Program is listed for each vector appearing in Tables 3-29, 3-30, 3-31, and comments are made for each comparison. The definition for each symbol in the listing can be found below.

<u>Symbol</u>	<u>Definition of Symbols</u>
X Y Z \dot{X} \dot{Y} \dot{Z}	Components of the position and velocity vector referenced to a geocentric, inertial, Cartesian, coordinate system. It is a right-handed system where the X-axis lies in the true equatorial plane in the direction of the Greenwich meridian at 0 ^h day of launch, the Z-axis is orthogonal to the true equatorial plane, and the Y-axis completes the right-handed system. The units are earth radii and earth radii/hour.
SEMI-MAJOR	Semimajor axis (feet)
ECCEN	Eccentricity of the orbit
INCL	Inclination of the orbit plane to the equator measured positive counter clockwise from the equatorial plane to the orbit plane at the ascending node (degrees)
NODE	Right ascension of the ascending node (degrees)
ARG PERIGEE	Argument of perigee measured positive in the direction of motion from the ascending node (degrees)
TRUE ANOM	True anomaly measured positive in the direction of motion (degrees)
PERIOD	Osculating period of the orbit (minutes)
APOGEE	Altitude of apogee above a reference sphere (nautical miles)
PERIGEE	Altitude of perigee above a reference sphere (nautical miles)
VEL-MAG	Magnitude of the inertial velocity vector (feet/second)

<u>Symbol</u>	<u>Definition of Symbols</u>
FLT PATH	Flight-path angle measured positive downward from the local vertical (degrees)
HEADING	Azimuth of the velocity vector measured positive east of true North (degrees)
DECLIN	Declination (degrees)
LONG	Longitude of the vehicle measured positive east of the Greenwich Meridian (degrees)
HEIGHT	Height of the vehicle above a reference sphere (nautical miles)
DELTA U	Difference between the RTCC and TRW components of the position and velocity vector in a vehicle-centered, coordinate system where the U-axis is collinear with the earth-centered inertial radius vector and is directed outward, the V-axis lies in the orbit plane and is orthogonal to the U-axis, and the W-axis completes the right-handed system.
DELTA V	
DELTA W	
DELTA UDOT	
DELTA VDOT	
DELTA WDOT	
DELTA POS	Magnitude of the difference between the RTCC position vector and the TRW position vector
DELTA VEL	Magnitude of the difference between the RTCC velocity vector and the TRW velocity vector

12/16/67 APCLLC RTCC COMPARISON
 EDALOC4 7LBS SS MANUAL, ACCEPT, NC UPD 1 EDIT 4 ITER VEP 1

TIME L.I.
 5/11/67 12 HRS 11 MIN 24.000 SEC
 TIME FROM LAUNCH
 0 DAYS 0 HRS 11 MIN 23.000 SEC
 X Y Z XDOT YDOT ZDOT
 -0.54900150E 00 0.67203830E 00 0.55316524E 00 -0.33503930E 01 -0.28466916E 01 0.13033637E 00 RTCC
 -0.54896045E 00 0.67210651E 00 0.55315471E 00 -0.33519766E 01 -0.28445585E 01 0.13239729E 00 TRW

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	PERIGEE	DECLIN	ARG PERIGEE	TRUE ANOM
21533596.00	0.00038601	32.57168484	43.01303720	183.57711029	263.24707413	RTCC
21533224.50	0.00038601	32.57075930	43.02078956	343.75769424	103.05573368	TRW
371.50	0.	0.00392554	-0.00774336	-160.18058395	160.19133949	(RTCC-TRW)

PERIOD	APGEE	PERIGEE	HEADING	DECLIN	LUNG	HEIGHT
88.19734097	104.02023315	101.28411865	87.97307587	32.51549006	305.89050293	102.80181885
88.19505405	103.95904541	101.22299154	87.96629715	32.51416638	305.89546585	102.86138916
0.00228691	0.06118774	0.06112671	0.00677872	0.00130367	-0.00496292	-0.05957031

VEL-MAG	FLT PATH	PERIGEE	DECLIN	LUNG	HEIGHT
25566.5029	90.02047443	101.28411865	32.51549006	305.89050293	102.80181885
25565.8521	89.98112297	101.22299154	32.51416638	305.89546585	102.86138916
0.65087891	0.03535146	0.00677872	0.00130367	-0.00496292	-0.05957031

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN LVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-362.	1250.	434.	-19.45	0.65	-1.83

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
1687.	19.54

- Notes:
- The exact location of perigee is difficult to determine due to the low eccentricity of the orbit. This accounts for the large difference in the argument of perigee.
 - The relatively large difference in the flight-path angle is reflected in DELTA UDOT.
 - In contrast to the velocity, the position was well determined.

12/18/67 60BS MS APUCC RTCC COMPARISON IEDIT 6ITER VEP 1
BDASOC6

TIME L.T. 9/11/67 12 HRS 11 MIN 24.000 SEC TIME FROM LAUNCH
0 DAYS 0 HRS 11 MIN 23.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
-0.54981026E 00	0.67204542E 00	0.55313252E 00	-0.33516354E 01	-0.28442623E 01	0.13004669E 00	00	RTCC
-0.54990045E 00	0.67210091E 00	0.55315478E 00	-0.33519766E 01	-0.28445585E 01	0.13239729E 00	00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
21527048.25	0.00035589	32.56862831	42.97319603	286.33890915	160.51890945 RTCC
21533224.50	0.00038601	32.57075930	43.02078050	343.75769424	103.05573368 TRW
-6176.25	-0.00003012	-0.00213095	-0.04758453	-57.41878510	57.46317577 (RTCC-TRW)

PERIGEE	APGEE	PERIGEE	DECLIN	LCNG	HEIGHT
88.15711403	102.83544922	100.31362915	32.51362324	305.89050293	102.77334595 RTCC
88.19505405	103.95904541	101.22299194	32.51418638	305.89561844	102.86138916 TRW
-0.03754003	-1.12359615	-0.90936275	-0.00056314	-0.00511551	-0.08804321 (RTCC-TRW)

VEL-MAG	FLI PATH	HEADING	DECLIN	LCNG	HEIGHT
25562.8196	89.99314117	87.95474049	32.51362324	305.89050293	102.77334595 RTCC
25565.8521	89.98112297	87.96625715	32.51418638	305.89561844	102.86138916 TRW
-3.03247070	0.01201820	0.02844334	-0.00056314	-0.00511551	-0.08804321 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-535.	1613.	-269.	-7.28	-3.03	-11.46

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	1720.
DELTA VEL	13.91

- Notes:
- The addition of the S-band data significantly reduced the difference in flight-path angle and DELTA UDOT.
 - The heading angle difference increased and is reflected in the increase in DELTA WDOT.

12/18/67 APULL RTCC COMPARISON
CRCCOIL 44URS PS MANUAL ACCEPT, NU UPD IEDIT 3ITER VEH 1

TIME L.I.
5/11/67 12 HRS 53 MIN 0. SEC
TIME FROM LAUNCH
0 DAYS 0 HRS 52 MIN 59.000SEC
X Y Z XDOT YDOT ZDOT
0.40183784E 00 -0.77873621E 00 -0.53943134E 00 0.37174990E 01 0.22920003E 01 -0.53995426E 00 RTCC
0.40175791E 00 -0.77876702E 00 -0.5394171CE 00 0.37178420E 01 0.22917192E 01 -0.54030076E 00 TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
21551734.CC	0.00086747	32.57337284	42.81410408	253.37470436	3.45420262 RTCC
21552916.00	0.00094548	32.57381248	42.81529140	251.36121941	5.46193838 TRW
-1162.00	-0.00088201	-0.00043964	-0.00118732	2.01348495	-2.00773576 (RTCC-TRW)

PERIOD	APGEE	PERIGEE	HEADING	DECLIN	LONG	HEIGHT
88.30875688	108.71417236	102.56036377	98.28254795	-31.61552048	103.50966835	102.56756592 RTCC
88.31606102	109.19976807	102.46385771	98.28619003	-31.61511588	103.51523495	102.51467896 TRW
-0.00726414	-0.4855557C	0.09646606	-0.00364208	-0.00040460	-0.00556660	0.05288696 (RTCC-TRW)

VEL-MAG	FLT PATH	PERIGEE	DECLIN	LONG	HEIGHT
25578.9495	89.95700928	102.56036377	-31.61552048	103.50966835	102.56756592 RTCC
25580.0305	89.99488258	102.46385771	-31.61511588	103.51523495	102.51467896 TRW
-1.08105465	0.00212665	0.09646606	-0.00364208	-0.00556660	0.05288696 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN LVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
321.	1785.	106.	-3.07	-1.08	0.32

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
1817.	3.27

- Notes:
- The venting is increasing the eccentricity of the orbit, and consequently, the difference in the argument of perigee is noticeably reduced.
 - The flight-path angle and heading angle differences have been reduced. This is reflected in the better velocity comparison.

12/18/67 APCLLC KTCC COMPARISON
 CRCS013 36CHS SS MANUAL, ACCEPT, NO UPD IEDIT 5ITER VEH1

TIME C.I. TIME FROM LAUNCH
 9/11/67 12 HRS 53 MIN 0. SEC 0 DAYS 0 HRS 52 MIN 59.000SEC

X	Y	Z	XDOT	YDOT	ZDOT
0.40181058E 00	-0.77875205E 00	-0.53939484E 00	0.37172053E 01	0.22923604E 01	-0.54077041E 00
0.40175791E 00	-0.77876702E 00	-0.53941710E 00	0.37178420E 01	0.22917192E 01	-0.54030076E 00

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	PERIGEE	INCL	NODE	ARG PERIGEE	TRUE ANOM
21551509.50	0.00088026	32.57453150	42.83688450	254.61586189	2.19223469 RTCC
21552916.00	0.00094948	32.57331248	42.81529140	251.36121941	5.46193838 TRW
-1406.50	-0.00006922	0.00071907	0.02159309	3.25464249	-3.26970369 (RTCC-TRW)

PERIOD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
86.30741405	108.72256470	102.47808838	-31.61363673	103.50966835	102.51705933 RTCC
88.31006102	105.15576807	102.46389771	-31.61511588	103.51364040	102.51467896 TRW
-0.00864657	-0.47720337	0.01419067	0.00147915	-0.00397205	0.00238037 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA U	DELTA V	DELTA W
25579.1804	89.99009551	98.25558945	14.	1178.	733.
25580.0305	89.99488258	98.28619003	DELTA U	DELTA V	DELTA W
-0.85009766	0.00321293	0.00339941	DELTA UDOT	DELTA VDOT	DELTA WDOT
			-2.83	-0.85	-5.13

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FI, FT/SEC)

DELTA U	DELTA V	DELTA W
14.	1178.	733.
DELTA UDOT	DELTA VDOT	DELTA WDOT
-2.83	-0.85	-5.13

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
1588.	5.52

- Notes:
- The S-band data have reduced DELTA UDOT, while DELTA WDOT and the heading angle difference have increased.
 - DELTA U has been reduced using the S-band data.

12/18/67 53LBS MS APULL RTCC COMPARISON 2EDIT 3ITER VEP 1
 WHSC013 MANUAL, ACCEPT, NO UPD

TIME L.T. 13 HRS 30 MIN 30.000 SEC
 9/11/67 13 HRS 30 MIN 29.000SEC

TIME FROM LAUNCH
 0 DAYS 1 HRS 30 MIN 29.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
0.37163150E-01	0.93782209E 00	0.42491533E 00	-0.405C8529E 01	-0.52732595E 00	0.15231508E 01	RTCC
0.3720628E-01	0.93786987E 00	0.42492511E 00	-0.409C4629E 01	-0.52714799E 00	0.15231981E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	PERIGEE	ARG PERIGEE	TRUE ANOM
21568598.00	C.00C6483	32.58657646	42.63534546	32.20379448	17.77340341 RTCC
21567047.25	C.0C035589	32.58776331	42.637C2059	26.10578918	23.8675127C TRW
1550.75	C.0001C893	-0.00118685	-0.00167513	6.09800529	-6.09410930 (RTCC-TRW)

PERICL	APGEE	PERIGEE	DECLIN	LONG	HEIGHT
88.41246986	11C.06277466	106.76275635	24.35778594	244.54832077	106.83966064 RTCC
88.40293407	109.42074585	106.69431763	24.35714531	244.55098152	107.00903320 TRW
0.00553575	0.642C2881	-0.13156128	0.00C64063	-0.00266075	-0.16937256 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
25558.1523	89.99186420	67.65427359	24.35778594	244.54832077	106.83966064 RTCC
25556.0144	89.99179935	67.65172291	24.35714531	244.55098152	107.00903320 TRW
2.13793545	0.00006485	0.00255108	0.00C64063	-0.00266075	-0.16937256 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1029.	935.	-124.	-1.14	2.14	-0.65

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PLS	DELTA VEL
1396.	2.51

- Notes:
- The effect of the venting during this portion of the flight raised perigee, and consequently, the difference in the argument of perigee is larger.
 - The downrange velocity difference is the largest of all velocity differences.

12/18/67 APOLO RTCC COMPARISON
 PLAC024 26LBS MS MANCAL,ACCEPT,NO UPD 1EDIT 2ITER VEH 1

TIME FROM LAUNCH
 C DAYS 1 HRS 35 MIN 47.00CSEC

TIME L.I.
 9/11/67 13 HRS 35 MIN 46.000 SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
-0.318306C2E 00	0.82655352E CC	0.52641245E CC	-0.3862125E 01	-0.19626195E 01	0.74690941E 00	RTCC	
-0.31823774E CC	0.82658242E 00	0.52639322E CC	-0.38619400E 01	-0.19624904E 01	0.74695716E 00	TRW	

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
21563525.00	C.00019301	32.575117624	42.59345770	46.18760633	25.42134476 RTCC
21561515.25	C.00017263	32.57526302	42.59485149	56.65409184	14.94944966 TRW
2409.75	0.00002937	-C.00008678	-C.00139380	-10.46648550	10.47189510 (RTCC-TRW)

PERILL	APCGEE	PERIGEE	HEADING	DECLIN	LONG	HEIGHT
88.38373756	108.32867432	106.95867920				RTCC
88.36892128	107.85968018	106.63449097				TRW
C.01481628	C.46855414	0.32418823				(RTCC-TRW)
VEL-MAG	FLI PATH	PERIGEE	HEADING	DECLIN	LONG	HEIGHT
25553.2778	89.59607658	78.60312462	30.72425175	266.54854584	107.13235474 RTCC	
25552.0415	89.59939060	78.59993553	30.72326350	266.55333710	107.10574341 TRW	
1.23632813	-0.003331402	0.00318909	0.00098825	-0.00479126	0.02661133 (RTCC-TRW)	

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
162.	1594.	58.	-0.41	1.24	-0.33

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA PCS	DELTA VEL
1603.	1.34

- Notes:
- The downrange position and velocity differences are the largest.
 - The orbit is becoming more circular due to the effects of venting.

12/15/67 540RS MS APOLLO RTCC COMPARISON 1EDIT 2ITER VEM 1

TIME U.T. 9/11/67 13 HRS 39 MIN 24.000 SEC
 TIME FROM LAUNCH 0 DAYS 1 HRS 39 MIN 23.000SEC
 X Y Z XDOT YDOT ZDOT
 -0.53712748E 00 0.68316365E 00 0.55352859E 00 0.33028319E 01 -0.27910639E 01 0.15247313E 00 PTCC
 -0.53706826E 00 0.68319878E 00 0.55353398E 00 -0.33027091E 01 -0.27910152E 01 0.15259095E 00 TPW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC TRW)
 SEMI-MAJOR ECCEN INCL
 21562474.75 0.00014950 32.57100201
 21561086.00 -0. 32.57178211
 1388.75 0.00014950 -0.00293016

APG PERIGEE TRUE ANOM
 81.89069271 4.41562271 RTCC
 155.07208824 291.22798920 TRW
 -73.18139553 286.81236649 (RTCC-TRW)

PERIOD APGEE PERIGEE
 88.37482166 107.93557739 106.87445068
 88.36628246 107.17648315 107.17648315
 0.00853920 0.75909424 -0.30203247

PTCC
 TPW
 (RTCC-TRW)

VEL-MAG FLT PATH HEADING
 25552.5042 89.99964523 87.64338779
 25551.7976 90.00300694 87.63924517
 0.70654297 -0.003336170 0.00404263

LONG HEIGHT
 282.76034927 107.12048340 PTCC
 282.76484680 107.10430908 TRW
 0.00449753 0.01617432 (RTCC-TPW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)
 DELTA U DELTA V DELTA W
 98. 1419. -255.
 98. 1419. -255.

DELTA WDOT
 -0.72

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)
 DELTA POS DELTA VEL
 1445. 1.03

- Notes: ● The argument of perigee is difficult to determine due to the eccentricity of the orbit.
 ● DELTA V is still the largest position difference.

12/15/67 APRIL 10 RTCC COMPARISON
 RDASC31 280RS MS MANUAL, ACCEPT, NO UPD 1 EDIT SYTD VEM 1

TIME H.T.
 9/11/67 13 HRS 41 MIN 24.000 SEC
 TIME FROM LAUNCH
 0 DAYS 1 HRS 41 MIN 23.000SEC
 X Y Z XDOT YDOT ZDOT
 -0.64441321E 00 0.58354309E 00 0.55248903E 00 -0.30340660E 01 -0.31757963E 01 -0.18456828E 00 RTCC
 -0.64436044E 00 0.58358561E 00 0.55300207E 00 -0.30339755E 01 -0.31757103E 01 -0.18445335E 00 TPW

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TPW)
 SEMI-MAJOR
 21562787.75 0.00012207 32.57119513 42.53577089
 21561417.50 0.00008631 32.57185745 42.53818941
 1370.25 0.00003575 -0.00006233 -0.000241852

PERIOD
 88.37674618 107.88073999 107.02334555
 88.36831951 107.53723145 106.92471313
 0.00842667 0.35250354 C.00863281

VEL-MAG
 25552.9734 90.00112534 92.85143757 32.45984125
 25552.2214 90.00415039 92.84784698 32.46078730
 0.75195313 -0.00302505 C.00359058 -0.00094604

APG PERIGEE
 134.97730827 349.49452972 RTCC
 152.82206371 301.64311218 TPW
 47.84565544 47.85141754 (RTCC-TPW)

RTCC
 TPW
 (RTCC-TPW)

LONG
 291.92122650 107.08108521 RTCC
 291.92559433 107.07272339 TPW
 0.00434783 0.00836182 (RTCC-TPW)

HEIGHT

DIFFERENCE BETWEEN RTCC AND TPW VECTORS IN UVA COORDINATES (FT, FT/SEC)
 DELTA U DELTA V DELTA W
 51. 1403. -287.
 DELTA W DELTA U DELTA V
 -0.31 0.75

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)
 DELTA POS DELTA VEL
 1433. 0.09

DELTA WDOT
 -0.56

- Notes: ● The velocity difference continues to decrease, since the data situation is good.
 ● DELTA V is still the largest position difference.

12/15/67 APOLLO RTCC COMPARISON
CYIC030 370RS MS MANUAL, ACCEPT, NC UPD IEDIT 217R VEH 1

TIME U.T. 9/11/67 13 HRS 51 MIN 0. SEC
TIME FROM LAUNCH 0 DAYS 1 HRS 50 MIN 59.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
-0.94870286E 00	-0.16765150E-01	0.4014797CE 00	-0.62026590E 00	-0.40345807E 01	-0.16353179E 01	PTCC	
-0.94864594E 00	-0.16713992E-01	0.40145935E 00	-0.62019488E 00	-0.40346101E 01	-0.16353317E 01	TRW	

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	APG PERIGEE	TRUE ANOM
21573942.75	0.00067415	32.59005455	42.45508957	142.34812355	351.31069946 RTCC
21572249.75	0.00066300	32.590050226	42.45674944	149.44687653	344.20708466 TRW
1693.00	0.00001114	-0.00044727	-0.00165987	-7.09875298	7.10361481 (PTCC-TRW)

PERION	APOGEE	PERIGEE	HEIGHT
88.44533253	111.68603516	106.89874268	106.93948364 RTCC
88.43492222	111.36761475	106.65985107	106.78250122 TRW
0.01041031	0.31842041	0.23889160	0.15698242 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG
25560.5962	90.00579929	113.81361061	22.93428093	332.69060516
25560.7240	90.01017952	113.81210232	22.93654919	332.60363403
-0.12866211	-0.00438923	C.00151730	-0.00225925	-0.00302887

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UTM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
954.	1303.	-354.	0.41	-0.13	-0.15

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
1653.	0.45

- Notes: This is the lowest velocity difference for the parking orbit and can be attributed to the good data coverage (ETR).
- DELTA V is still the largest position difference.

12/15/67 APOLLO RTCC COMPARISON
 CR0032 510RS MS MANUAL, ACCEPT, NO UPD 2ECIT 3ITEC VEH 1

TIME U.T.
 9/11/67 14 HRS 26 MIN 12.000 SEC

TIME FROM LAUNCH
 0 DAYS 2 HRS 26 MIN 11.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
0.67706313E 00	-0.54762247E 00	-0.54983924E 00	0.20077980E 01	0.32968795E 01	0.30313246E 00	RTCC	
0.67692107E 00	-0.54763477E 00	-0.54981383E 00	0.29077941E 01	0.32871152E 01	0.30292237E 00	TRW	

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	APOG PERIGEE	TRUE ANOM
21571666.00	0.00108841	32.57164335	42.29450512	251.59761238	25.78332973 RTCC
21569018.25	0.00102858	32.57257557	42.30137157	256.17194448	21.19767642 TRW
2647.75	0.00005983	-0.00053222	-0.00686646	-4.57423210	4.58565331 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE
88.43133259	112.78179932	105.05352783
88.41505241	112.13317871	104.83065796
0.01628017	0.64862061	C.22286987

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
25569.7947	89.97319412	85.30838203	-32.26886463	103.88398457	105.47500610 RTCC
25570.7192	89.97903538	85.31540298	-32.27072001	103.80049435	105.12918091 TRW
-0.92456055	-0.00584126	-0.00702095	0.00189537	-0.00650978	0.34582520 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
2101.	2120.	526.	0.00	-0.92	1.58

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
3031.	1.84

Note: ● A noticeable increase in position and velocity differences is observed which can be explained by the lack of tracking data between CYICO2 and CROCO2.

12/15/67 APOLLO RTCC COMPARTISON
WHSC047 100RS MS MANUAL, ACCFOT, MIN UPD 1 EDIT 3 ITER VEH1

TIME U.T.
9/11/57 15 HRS 5 MIN 18.000 SEC
TIME FROM LAUNCH
0 DAYS 3 HRS 5 MIN 17.000 SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
-0.39326445E 00	0.78502361E 00	0.54054213E 00	0.37305138E 01	-0.22442219E 01	0.53895568E 00	RTCC	
-0.39319620E 00	0.78503295E 00	0.54049316E 00	0.37305204E 01	-0.22442372E 01	0.53892444E 00	TRW	

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	APG PERIGEE	TRUE ANOM
21577562.00	0.00014950	32.57505131	42.12145110	49.76107693	27.07393885 RTCC
21575705.25	-0.	32.57406855	42.12173605	123.57276535	313.25813293 TRW
1856.75	0.00014950	0.00098276	0.00021505	-73.81169842	-286.18419266 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
88.46759120	110.41897583	109.75711670	31.61801744	249.65951157	109.61373901 RTCC
88.45617199	109.58248901	109.58248901	31.61647773	249.66435051	109.44702148 TRW
0.01141930	0.93648682	-0.22537231	0.00153971	0.00493894	0.16671753 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING
25543.4941	99.99773788	81.72064590
25543.5947	90.00232506	81.71844578
-0.10058594	-0.00458717	0.00220013

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UTM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
1013.	1619.	350.	0.13	-0.10	0.15

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA UVS	DELTA VEL
1942.	0.22

Note: • The velocity difference is very good considering CALCO2 is the only data that have been accepted by the RTCC since GROCO2.

12/18/67 APOLLO RTCC COMPARISON
 800048 320RS SS MANUAL, ACCEPT, NO UPD 1 EDIT 4 ITER VEH1

TIME U.T.
 9/11/67 15 HRS 17 MIN 6.000 SEC

TIME FROM LAUNCH
 0 DAYS 3 HRS 17 MIN 5.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
-0.97073530E 00	0.10981362E 00	0.50276720E 00	-0.23696384E 01	-0.46952993E 01	-0.42321099E 00	RTCC
-0.97067071E 00	0.10986693E 00	0.50271863E 00	-0.23693544E 01	-0.46853587E 01	-0.42298000E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
49041956.00	0.57895895	30.30660748	55.24506569	71.16217995	43.77038240 RTCC
49022197.00	0.57880108	30.30338359	55.25133419	71.15791130	43.76639700 TRW
19759.00	0.00015787	0.00322390	-0.00626850	0.00426865	0.00398540 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE
303.13236618	9302.87866211	-42.58681641
302.94918442	9296.47033691	-43.08227539
0.18318176	6.40832520	0.09545898

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
30618.2944	74.22876358	103.84194183	27.23223519	303.63965988	342.55801392 RTCC
30617.7512	74.23302937	103.83609867	27.23137116	303.64319611	342.30331421 TRW
0.54321289	-0.00426579	0.00584316	0.00086403	0.00353622	0.25469971 (PTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
1548.	1141.	638.	0.88	0.32	-1.94

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
2026.	2.16

- Notes: ● This was a single station RTCC fit made after S-IVB cutoff using 32 data points.
 ● The predicted apogee difference is 6 nautical miles.

12/18/67 APOLO RTCC COMPARISON
 ANT050 520BS MS MANUAL, ACCEPT, NO UPD IECIT 3ITER VEH 1

TIME 11.7
 9/11/67 15 HRS 17 MIN 6.000 SEC

TIME FROM LAUNCH
 0 DAYS 3 HRS 17 MIN 5.0000SEC

X	Y	Z	XDOT	YDOT	ZDOT
-0.97072922E 00	0.10981758E 00	0.50271951E 00	-0.23696980E 01	-0.46853369E 01	-0.42283523E 00
-0.97067071E 00	0.10986693E 00	0.50271863E 00	-0.23693544E 01	-0.46853587E 01	-0.42298000E 00

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
49038681.50	0.57895718	30.20255926	55.25069332	71.14980221	43.77816391 RTCC
49022197.00	0.57880108	30.30338355	55.25133419	71.15791130	43.76639700 TRW
16484.50	0.00015610	-0.00038433	-0.000064087	-0.00810909	0.01176691 (RTCC-TRW)

PERION	APOGEE	PERIGEE
303.10200882	9302.01330566	-43.19940186
302.94918442	9296.47033691	-43.08227535
0.15282440	5.54296875	-0.11712646

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
30618.4692	74.22609806	103.83772278	27.23015738	303.63965988	342.46572876 RTCC
30617.7512	74.23302937	103.83609867	27.23137116	303.64292145	342.30331421 TRW
0.71801758	-0.00693130	0.00162411	-0.00121379	0.00326157	0.16241455 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
987.	1247.	-195.	2.16	0.14	-0.14

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
1602.	2.17

Note: • The predicted apogee difference is reduced by the addition of ANT03 data.

12/18/67 APOLLO RTCC COMPARISON
 8DQCO58 6208S MS MANUAL,ACCEPT,NO UPD 2EDIT 2ITER VEH 1

TIME U.T.
 9/11/67 15 HRS 20 MIN 18.000 SEC
 TIME FROM LAUNCH
 0 DAYS 3 HRS 20 MIN 17.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
-0.10770611E 01	-0.14065336E 00	0.47032444E 00	-0.16325280E 01	-0.46776113E 01	-0.77500682E 00	00	RTCC
-0.10769841E 01	-0.14060411E 00	0.47031038E 00	-0.16320826E 01	-0.46776375E 01	-0.77532650E 00	00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
49045044.50	0.57897780	30.2070941C	55.23767757	71.17607784	56.88097763 RTCC
49027551.50	0.57880750	30.30799985	55.23626137	71.18755150	56.86862850 TRW
17493.00	0.00017030	-C.C009C575	0.00141621	-0.01147366	0.01234913 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE
303.16100311	9303.83325195	-42.92452676
302.99882126	9297.91333008	-42.76293545
0.16218185	5.91992188	-0.1619873C

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
29148.1682	69.77715492	109.81532383	23.41248488	316.73320007	635.12170410 RTCC
29147.7549	69.78539658	109.81562996	23.41345286	316.73525238	634.84088135 TRW
0.41333008	-0.00824165	-C.C0030613	-0.00096798	0.00205231	0.28082275 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
1706.	907.	-118.	3.08	-0.69	0.49

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1936.	3.19

- Notes: • More data from BDQCO3 are added to the fit with a maximum elevation of 14 degrees.
 • The fact that Bermuda lies along the vehicle track makes it difficult to determine U and UDOT.

12/18/67 APOLLO RTCC COMPARISON
 ANT059 420RS MS MANUAL, ACCEPT, NO UPD 2EDIT 2ITER VEH 1

TIME U.T. 9/11/67 15 HRS 22 MIN 18.000 SEC
 TIME FROM LAUNCH
 0 DAYS 3 HRS 22 MIN 17.000SEC

X	Y	Z	XDOT	YDOT	ZDOT
-0.11245284E 01	-0.29535883E 00	0.44153725E 00	-0.12228340E 01	-0.45970410E 01	-0.94554306E 00
-0.11244355E 01	-0.29531048E 00	0.44152647E 00	-0.12221895E 01	-0.45971460E 01	-0.94570591E 00

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
49045100.00	0.57895759	30.311409CC	55.22689009	71.19280529	64.10400009 PTCC
49028595.50	0.57878703	30.31067657	55.23028231	71.20217514	64.09025383 TRW
16504.50	0.00017056	0.00073242	-0.00339222	0.00936985	0.01374626 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
303.16151428	9303.68457031	-42.75793457	20.79485273	323.50901031	841.85177612 RTCC
303.00849915	9298.01953125	-42.52526011	20.79605699	323.51015091	841.50985718 TRW
0.15301514	5.66503906	-0.23257446	-0.00120425	-0.00114059	0.34191895 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
28191.4163	67.42686367	112.56408882	20.79485273	323.50901031	841.85177612 RTCC
28191.2346	67.43602943	112.56195831	20.79605699	323.51015091	841.50985718 TRW
0.18164063	-0.00916576	C.C0213051	-0.00120425	-0.00114059	0.34191895 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
2077.	658.	-319.	3.58	-1.29	-0.92

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
2202.	3.91

Note: • DELTA U and DELTA UDOT are the largest position and velocity component differences.

12/21/67 APCLLC RTCC COMPARISON
 ANTC061 180ES SS MANUAL, ACCEPT, NO UPD IEDIT 4ITER VEH 1

TIME L.I. TIME FROM LAUNCH
 9/11/67 15 HRS 28 MIN 36.000 SEC 0 DAYS 3 HRS 28 MIN 35.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
-0.11961550E 01	-0.75658346E 00	0.32245941E 00	-0.24604186E 00	-0.41781072E 01	-0.12873707E 01	RTCC
-0.11964096E 01	-0.75648129E 00	0.32202002E 00	-0.23342804E 00	-0.41808146E 01	-0.12821801E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)			
SEMI-MAJOR	ECCEN	INCL	TRUE ANOM
50464708.50	0.59242199	30.46434212	82.41107273 RTCC
50487568.50	0.59133110	30.30565482	82.14126301 TRW
-22860.00	0.00109088	0.15864730	0.26980972 (RTCC-TRW)

PERIOD			
APCGEE	PERIGEE	RTCC	TRW
316.41880417	9784.41577148	-56.21414185	RTCC
316.63382721	9781.34265137	-45.61639404	TRW
-0.21502304	3.07312012	-10.59774780	(RTCC-TRW)

VEL-MAG			
DELTA U	DELTA V	DELTA W	HEIGHT
25453.0371	61.42628288	117.86746025	1558.05630493 RTCC
25455.1917	61.54415512	117.69868851	1558.14596558 TRW
-2.15454102	-0.11787224	0.16877174	-0.08966064 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FI, FT/SEC)			
DELTA U	DELTA V	DELTA W	DELTA WDOT
-546.	-716.	10414.	-60.96

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)			
DELTA PCS	DELTA VEL	DELTA VDOT	DELTA WDOT
10453.	80.83	-27.27	-60.96

- Notes: ● This is a single station fit immediately following SPS-1 cutoff. There were a total of 18 data points in the fit with a maximum elevation of 7 degrees.
- Note that the out-of-plane differences are the largest.

12/21/67 APCLLC RTCC COMPARISON
 ASCC066 6208S MS MANUAL, ACCEPT, NO UPD SEDIT 4ITER VEH 1

TIME L.T. 9/11/67 15 HRS 29 MIN 18.000 SEC
 TIME FROM LAUNCH
 0 DAYS 3 HRS 29 MIN 17.000SEC

	X	Y	Z	XDOT	YDOT	ZDOT	
-0.11983633E 01	-0.80504196E 00	0.30711341E 00	-0.14476870E 00	-0.41230847E 01	-0.13067784E 01	RTCC	
-0.11986111E 01	-0.80492105E 00	0.30692276E 00	-0.14468545E 00	-0.41229751E 01	-0.13055242E 01	TRW	

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	INCL	PERIGEE	TRUE ANOM
50501549.50	30.33181334	55.21302032	83.86557388 RTCC
50486508.50	30.30610538	55.21055412	83.88378334 TRW
15041.00	0.02570796	0.00246620	-0.01820946 (RTCC-TRW)

PERICL	APCGEE	PERIGEE	RTCC
316.76536560	9785.67846680	-45.35009766	TRW
316.62386703	9780.93017578	-45.55264282	(RTCC-TRW)
0.14149857	4.74829102	0.20254517	

VEL-MAG	FLT PATH	DECLIN	LONG	HEIGHT
25155.2859	61.05424595	12.00960839	340.92207336	1641.81875610 RTCC
25152.4619	61.05291176	12.00125349	340.93154144	1642.14791870 TRW
2.82397461	0.00133419	0.00835490	-0.00946808	-0.32916260 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-2001.	2288.	6321.	-0.78	3.65	-6.31

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
7014.	7.33

Note: • These data significantly reduced the total velocity differences.

12/21/67 APCLLG RTCC COMPARISON
ACNS067 68CBS MS MANUAL, ACCEPT, NO UPD 2EDIT SITER VEH 1

TIME L.T.
9/11/67 15 HRS 25 MIN 18.000 SEC

TIME FROM LAUNCH
0 DAYS 3 HRS 29 MIN 17.000SEC

X	Y	Z	XDCT	YDOT	ZDOT	RTCC
-0.11983565E 01	-0.80504451E 00	0.30707752E 00	-0.14393160E 00	-0.41231826E 01	-0.13050380E 01	RTCC
-0.11986111E 01	-0.80492105E 00	0.30692276E 00	-0.14468545E 00	-0.41229751E 01	-0.13055242E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJCH	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50475934.50	0.59126056	30.30494761	55.23476744	71.76272011	83.88719368 RTCC
50486508.50	0.59131485	30.30610538	55.21055412	71.78196907	83.88378334 TRW
-10574.00	-0.00005429	-0.00115776	0.02421331	-0.01924896	0.00341034 (RTCC-TRW)

PERIOD	APCCEE	PERIGEE	DECLIN	LONG	HEIGHT
316.52439495	9777.70971680	-45.81286621	12.00827730	340.92207336	1641.77993774 RTCC
316.62386703	9780.53017578	-45.55264282	12.00125349	340.93176651	1642.14791870 TRW
-0.09947205	-3.22045898	-0.26022339	0.00702381	-0.00969315	-0.36798096 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-2237.	2730.	5744.	-2.31	1.45	4.60

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
6742.	5.35

- Notes:
- These data again had more effect on reducing the total velocity difference than the total position difference.
 - The geometry of the pass is similar to near-earth orbit because of the rapid change in the observation angles.

12/21/67 APLLQ RTCC COMPARISON
ACNS065 80085 MS MANUAL, ACCEPT, NO UPD IEDIT 5ITER VET 1

TIME L.T. TIME FROM LAUNCH
9/11/67 15 HRS 36 MIN 6.000 SEC 0 DAYS 3 HRS 36 MIN 5.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
-0.11736828E 01	-0.12399675E 01	0.15021317E 00	0.52839935E 00	-0.35542959E 01	-0.14370636E 01	01	RTCC
-0.11735988E 01	-0.12398411E 01	0.15005439E 00	0.52663948E 00	-0.35540390E 01	-0.14382084E 01	01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50469541.00	0.59103441	30.2855413C	55.23752832	71.78450584	98.20751095 RTCC
50476354.50	0.59117797	30.30837C35	55.209C6878	71.78764725	98.22259521 TRW
-6813.50	-0.00014356	-0.02282906	0.02845955	-0.00314140	-0.01508427 (RTCC-TRW)

PERIOD
316.46425625
316.52835083
-0.06409454

APCGEE
9774.15686035
9777.13366699
-2.57680664

PERIGEE
-44.36453247
-45.09844971
0.73391724

VEL-MAG
22495.5261
22495.2329
0.29321289

FLI PATH
57.42601871
57.41573763
C.01028109

HEADING
119.90440178
119.92844582
-0.02404404

DECLIN
5.02794808
5.02229333
0.00565475

LONG
351.89676285
351.90737534
-0.01061249

HEIGHT
2461.39804077 RTCC
2461.78042603 TRW
-0.38238525 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-2324.	3571.	637C.	-5.34	3.76	10.41

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS
7858.
DELTA VEL
12.29

- Notes:
- This is still a period of rapid change in the observation angles.
 - The fact that the total position and velocity is worse can be attributed to the bad ASCCO3 data having an effect on the trajectory. This is in essence a single station fit.
 - There is a hump in the doppler residual pattern during this period.

12/21/67 APCLO RTCC COMPARISON
 ASCC068 80C85 MS MANUAL, ACCEPT, NO UPD 2EDIT 4ITER VEH 1

TIME L.T.
 9/11/67 15 HRS 43 MIN 42.000 SEC

TIME FROM LAUNCH
 0 DAYS 3 HRS 43 MIN 41.000SEC

X	Y	Z	XDQT	YDQT	ZDQT
-0.10753204E 01	-0.16522875E 01	-0.34524490E-01	0.98807733E 00	-0.29698029E 01	-0.14638234E 01
-0.10756744E 01	-0.16521944E 01	-0.34683068E-01	0.98702398E 00	-0.29698874E 01	-0.14644095E 01

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50459665.50	0.59097507	30.29619908	55.22598982	71.78142643	110.20770550 RTCC
50467887.50	0.55108093	30.30877781	55.20896864	71.78614902	110.21125412 TRW
-8222.00	-0.00010586	-0.01257873	0.01702118	-0.00472260	-0.00354862 (RTCC-TRW)

PERIOD	APQEE	PERIGEE	DECLIN	LONG	HEIGHT
316.37137985	9771.07812500	-44.53634644	-1.00330634	0.36262840	3349.04605103 RTCC
316.44871140	9774.11022949	-44.86215210	-1.00785495	0.37272684	3349.45193481 TRW
-0.07733154	-3.03210449	0.32580566	0.00454861	-0.01009843	-0.40588379 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA U	DELTA V	DELTA W
20084.3923	55.12921333	120.28115845	-2467.	4626.	6496.
20084.5088	55.12261724	120.29360867	-3.81	2.51	5.34
-0.11645508	0.00659609	-0.01245022	DELTA UDOT	DELTA VDOT	DELTA WDOT

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W
-2467.	4626.	6496.

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
8348.	7.02

Note: ● The total differences in position and velocity have become larger with the largest component differences in the out-of-plane direction.

12/21/67 APOLLO RTCC COMPARISON
ASCC074 800BS MS MANUAL, ACCEPT, NO UPD IEDIT 3ITER VEH 1

TIME L.T. 9/11/67 15 HRS 59 MIN 42.000 SEC
TIME FROM LAUNCH
0 DAYS 3 HRS 59 MIN 41.000SEC

X	Y	Z	XDCT	YDOT	ZDOT	RTCC
-0.73950177E 00	-0.23071088E 01	-0.41396367E 0C	0.14527831E 01	-0.19949207E 01	-0.13614724E 01	RTCC
-0.74006566E 00	-0.23070571E 01	-0.41421164E 0C	0.14515949E 01	-0.19950584E 01	-0.13622235E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL
50457434.00	0.55086910	3C.28520679
50458772.50	0.59099583	30.30751753
-1338.50	-0.00012673	-0.02231073

ARG PERIGEE	TRUE ANOM
71.79454041	127.71575832 RTCC
71.78019619	127.72737980 TRW
0.01434422	-0.01162148 (RTCC-TRW)

PERIOD	APCGEE	PERIGEE
316.35039520	9769.61401367	-43.80657959
316.36298752	5771.01684570	-44.76882935
-0.01259232	-1.40283203	0.96224976

RTCC
TRW
(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING
16383.0554	53.79589653	118.83162880
16382.1772	53.78695345	118.85368156
0.88220215	0.00894308	-0.02205276

DECLIN	LONG	HEIGHT
-9.69630265	11.63275480	5023.31726074 RTCC
-9.70151722	11.64582777	5023.87866211 TRW
0.00521457	-0.01307297	-0.56140137 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-3413.	7871.	5681.	-3.57	3.70	6.40

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
12936.	8.21

- Notes: • The vehicle is moving away from the station at this point. Therefore, the X and Y angles are not changing as rapidly.
- The out-of-plane component differences are still the largest.

12/21/67 APLLCC RTCC COMPARISON
ACAS075 80C8S MS MANUAL, ACCEPT, NO UPD IEDIT 3ITER VEH 1

TIME L.I.
9/11/67 16 HRS 0 MIN 6.000 SEC

TIME FROM LAUNCH
0 DAYS 4 HRS 0 MIN 5.000SEC

X	Y	Z	XDOT	YDOT	ZDOT
-0.72578644E 00	-0.23203408E 01	-0.42302611E 00	0.14592745E 01	-0.19743550E 01	-0.13577943E 01
-0.73036648E 00	-0.23202890E 01	-0.42328078E 00	0.14581234E 01	-0.19745141E 01	-0.13585033E 01

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50456505.50	0.59087277	30.28648663	55.21657896	71.79266834	128.06863022
50458638.50	0.59099481	30.30747652	55.20837069	71.78008080	128.07929993
-1733.00	-0.00012204	-0.02098989	0.00820827	0.01258755	-0.01066971

PERIOD	APGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.34542465	5765.50598145	-43.87268066	-9.86580765	11.84521806	5061.44299316
316.36171722	5770.97314453	-44.76947021	-9.87113404	11.85861552	5062.01623535
-0.01629257	-1.46716309	0.89678955	0.00532639	-0.01339746	-0.57324219

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
16307.8903	53.80342722	118.77984905	-9.86580765	11.84521806	5061.44299316
16307.0576	53.79481602	118.80047989	-9.87113404	11.85861552	5062.01623535
0.832264160	0.00861120	-0.02063084	0.00532639	-0.01339746	-0.57324219

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-3485.	8117.	9943.	-3.55	3.63	6.06

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
13300.	7.91

Note: • The out-of-plane component differences are the largest.

12/21/67 APCLLG RTCC COMPARISON
 ASCC086 59GBS MS MANUAL, ACCEPT, NO UPD LEDIT 3ITER VEF 1

TIME L.T.
 9/11/67 16 HRS 44 MIN 6.000 SEC

TIME FROM LAUNCH
 0 DAYS 4 HRS 44 MIN 5.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
0.44161181E 00	-0.31165799E 01	-0.12506677E 01	0.16013425E 01	-0.37191930E 00	-0.89205687E 00	00	00
0.44079432E 00	-0.31167528E 01	-0.12510529E 01	0.16008581E 01	-0.37226713E 00	-0.89246364E 00	00	00

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50452010.00	0.59088072	30.28922462	55.20293140	71.79044151	155.27256012 RTCC
50452683.50	0.59097145	30.30378389	55.20335722	71.77574635	155.27589417 TRW
-673.50	-0.00009073	-0.01455927	-0.00042582	0.01469517	-0.00333405 (RTCC-TRW)

PERIOD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.29538507	5768.29016113	-44.26834106	-21.66920924	26.33755445	8223.53100586 RTCC
316.30571747	9769.21997070	-44.97628784	-21.67490935	26.35273123	8224.20227051 TRW
-C.00633240	-0.92580957	0.70794678	0.00570011	-0.01517677	-0.67126465 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA U	DELTA V	DELTA W
10872.0695	61.92036867	111.69690132	DELTA UDOT	DELTA VDOT	DELTA WDOT
10871.1897	61.91475010	111.71258163	-2.37	2.26	2.63
0.87976074	0.00561857	-0.01568031			

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W
-4081.	13599.	13004.

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
19253.	4.20

Note: • The range difference is still increasing.

12/21/67 APELLC RTCC COMPARISON
ACNS088 800BS MS MANUAL,ACCEPT,NO UPD IEDIT 3ITER VEH 1

TIME U.T.
9/11/67 16 HRS 57 MIN 42.000 SEC

TIME FROM LAUNCH
0 DAYS 4 HRS 57 MIN 41.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
0.79762577E 00	-0.31617533E 01	-0.14364762E 01	0.15352016E 01	-0.34419310E-01	-0.74779324E 00	00	RTCC
0.79670337E 00	-0.31620104E 01	-0.14369552E 01	0.15348199E 01	-0.34807236E-01	-0.74818111E 00	00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50451510.50	0.59088326	30.28837419	55.20121479	71.79094028	161.27500153 RTCC
50452179.50	0.59097472	30.30301547	55.20153809	71.77623844	161.27718735 TRW
-669.00	-0.00009146	-0.01464128	-C.00032330	0.01470184	-0.00218582 (RTCC-TRW)

PERIOD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.29468155	9768.18041992	-44.32302856	-23.77475815	29.02038121	8830.08288574 RTCC
316.30057561	9769.11523438	-45.03738403	-23.78169274	29.03720045	8830.82312012 TRW
-0.000629807	-0.93481445	0.71435547	0.00685459	-0.01681924	-0.74023438 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
9928.0305	66.65711971	109.33961773	-23.77475815	29.02038121	8830.08288574 RTCC
9927.0698	66.65180202	109.35532856	-23.78169274	29.03720045	8830.82312012 TRW
C.96069336	0.00531769	-0.01571083	0.00685459	-0.01681924	-0.74023438 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-4501.	15526.	15103.	-2.41	2.09	2.22

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
22405.	3.88

Note: • The range difference continues to increase and has reached its maximum difference.

12/21/67 APLLC RTCC COMPARISON
ACAS091 800BS MS MANUAL, ACCEPT, NO UPD IEDIT 2ITER VET 1

TIME U.T. 17 HRS 13 MIN 42.000 SEC
9/11/67 17 HRS 13 MIN 41.000SEC
TIME FROM LAUNCH
0 DAYS 5 HRS 13 MIN 41.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
0.11929670E 01	-0.31237587E 01	-0.16135575E 01	0.14259689E 01	0.31180252E 00	-0.57996950E 00	00	00
0.11921116E 01	-0.31240831E 01	-0.16140594E 01	0.14257315E 01	0.31144767E 00	-0.58030266E 00	00	00

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NOOE	ARG PERIGEE	TRUE ANOM
50451418.00	0.55089680	30.28955674	55.19630337	71.79257298	167.71328545 RTCC
50451803.50	0.59097926	30.30227447	55.19933558	71.77727985	167.71425438 TRW
-385.50	-0.00008246	-0.01271772	-0.00303221	0.01529312	-0.00096893 (RTCC-TRW)

PERIOD	APGEE	PERIGEE	DECLIN	LONG	HEIGHT	RTCC	TRW	(RTCC-TRW)
316.29381943	5768.26875883	-44.44165039	-25.76024342	31.75372386	9345.24584961 RTCC	RTCC	TRW	(RTCC-TRW)
316.29744335	9769.05444336	-45.10043335	-25.76667619	31.76940250	9345.93090820 TRW			
-0.00362396	-C.78564453	0.65878296	0.00643277	-0.01567864	-0.68505859 (RTCC-TRW)			

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA LDDT	DELTA VDDT	DELTA WDDT
-4166.	15873.	13807.	-2.13	1.62	1.65

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
21446.	3.15

- Notes: • DELTA V has become the largest position difference.
• The geometry of the pass is beginning to simulate translunar geometry.

12/21/67 APOLLO RTCC COMPARISON
 ASCC092 800RS MS MANUAL, ACCEPT, NO UPD LEDIT 4ITER VEH 1

TIME U.T. TIME FROM LAUNCH
 9/11/67 17 HRS 16 MIN 36.000 SEC 0 DAYS 5 HRS 16 MIN 35.000SEC

X	Y	Z	XDCI	YDOT	ZDOT	
0.12612231E 01	-0.31073180E 01	-0.1640977CE 01	0.14030834E 01	0.36983874E 00	-0.54963785E 00	RTCC
0.12604733E 01	-0.310762C8E 01	-0.16413740E 01	0.14028723E 01	0.36953460E 00	-0.54995178E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50451609.00	0.55090418	30.29065895	55.19355488	71.79346466	168.82984734 RTCC
50451751.5C	0.55058CC9	30.30215573	55.19892740	71.77751255	168.83074188 TRW
-142.50	-0.00007591	-0.01149678	-0.00537252	0.01595211	-0.00089455 (RTCC-TRW)

PERIOD	APGCEE	PERIGEE
316.29561615	9768.38000488	-44.45005127
316.29695511	9769.04772949	-45.11080933
-0.00133896	-0.66772461	0.62075806

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
9019.1107	74.76424503	105.98947430	-26.07386494	32.21832705	9416.55407715 RTCC
9018.2268	74.76089096	106.00354958	-26.07934570	32.23214102	9417.15112305 TRW
0.88391113	0.00335407	-0.01407528	0.00548077	-0.01381397	-0.59704590 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-363C.	14205.	11848.	-1.86	1.42	1.57

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
18850.	2.82

- Notes: • The period of bad ASCCO3 ended at 17 hours, 12 minutes, 30 seconds.
 • This is the last comparison made using Segment 4.

12/21/67 APOLLO RTCC COMPARISON
ACNS007 800BS MS MANJAL, ACCEPT, NC UPC 1ECIT 2ITER VEH 1

TIME U.T. 9/11/67 17 HRS 39 MIN 12.000 SEC
TIME FROM LAUNCH 0 DAYS 5 HRS 39 MIN 11.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
0.17512023E 01	-0.28882954E 01	-0.18041467E 01	0.11951565E 01	0.784222498E 00	-0.31170402E 00	00	00
0.17514564E 01	-0.28884185E 01	-0.18036837E 01	0.11950199E 01	0.78432889E 00	-0.31200220E 00	00	00

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	APG PERIGEE	TRUE ANOM
50451813.00	0.59097683	30.30417323	55.17815161	71.79490063	177.22532845 PTCC
50451799.50	0.59097436	30.30166411	55.20992613	71.76768017	177.22486877 TRW
13.50	0.00000247	0.00250912	-0.03177452	0.02632046	0.00045967 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	LONG	HEIGHT
316.29753113	9769.03649902	-45.07958984	35.70649099	9746.69775391 RTCC
316.29740524	9769.01281738	-45.05999756	35.70388842	9746.66650391 TRW
0.00012589	0.02368164	-0.01959229	0.00260258	0.03125000 (RTCC-TRW)

VEL-MAG	FLT PATH	LEADING	DECLIN
8504.3813	86.00584412	101.81939583	-28.10811424
8504.4258	86.00522804	101.83224297	-28.10033226
-0.044443359	0.00061607	-0.01284313	-0.00778198

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
188.	-912.	-11311.	0.00	-0.04	2.00

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
11349.	2.00

- Notes:
- The difference in the inclination of the orbit plane has been noticeably reduced. This is due to the increase in the inclination of the orbit plane as determined by the RTCC.
 - The out-of-plane component differences are much larger than the other component differences.
 - Two batches of CROCO3 data have come into the RTCC since ASCCO92. The Carnarvon data were the major factor in more accurately determining the inclination of plane. However, the bad refraction problem will degrade the solution until the elevation gets above 10 degrees. This occurs about 18 hours and 10 minutes, GMT.

12/21/67 APOLO RTCC COMPARISON
ASCC098 800RS MS MANUAL, ACCEPT, NO LPC IECIT 2ITER VEH 1

TIME U.T.
9/11/67 17 HRS 45 MIN 42.000 SEC

TIME FROM LAUNCH
0 DAYS 5 HRS 45 MIN 41.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	PTCC	TRW
0.18769382E 01	-0.27973963E 01	-0.18341716E 01	0.11256659E 01	0.89312085E 00	-0.24201367E 00	PTCC	
0.18771927E 01	-0.27975145E 01	-0.18337170E 01	0.11255228E 01	0.89322797E 00	-0.24232421E 00	TRW	

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	MODE	ARG PERIGEE	TRUE ANOM
50451700.50	0.59097989	30.3045156C	55.17744732	71.79432106	179.58642387 PTCC
50451712.50	0.59097692	30.30151351	55.20908689	71.76824379	179.5859108C TRW
-12.00	0.00000297	0.00300165	-0.03163958	0.02607727	0.00051308 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE
316.29647446	9769.03271484	-45.11257935
316.29658890	9769.01110840	-45.0871582C
-0.00011444	0.02160645	-0.02542114

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
8470.1283	89.40248871	100.57009025	-28.56697536	36.70804930	9768.53540039 RTCC
8470.1680	89.40175152	100.58307743	-28.55929828	36.70557690	9768.51269531 TRW
-0.03967285	0.00073719	-0.01298714	-0.00767708	0.00247240	0.02270508 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
138.	-1015.	-11130.	-0.00	-0.04	2.08

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
11177.	2.08

Note: • This comparison is made very near apogee which occurred at 17 hours, 46 minutes, and 50.54 seconds, GMT. The differences in the inclination of the orbit plane accounts for all the difference observed in the out-of-plane direction.

12/21/67
ACNS100 800RS MS APOLLO RTCC COMPARISON
MANUAL, ACCEPT, NO UPD 1ECIT 2ITER VEH 1

TIME U.T.
9/11/67 17 HRS 56 MIN 24.000 SEC

TIME FROM LAUNCH
0 DAYS 5 HRS 56 MIN 23.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.20667951E 01	-0.26227387E 01	-0.18669236E 01	0.10012065E 01	0.10641616E 01	0.12518200E 00	RTCC
0.20670038E 01	-0.26228265E 01	-0.18665611E 01	0.10010426E 01	0.10642762E 01	-0.12552255E 00	TRW

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50451688.50	0.59098060	30.20321056	55.17557669	71.79580975	183.47393036 RTCC
50451630.50	0.59097967	30.30126023	55.20740557	71.76950645	183.47346687 TRW
58.00	0.00000093	0.00235033	-0.003182888	0.02630329	0.00046349 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	HEADING	DECLIN	LONG	HEIGHT
316.29636002	9769.03564453	-45.11932373	98.45253468	-29.20909643	38.40429258	9734.05517578 RTCC
316.29581833	9769.01245117	-45.11550903	98.46654587	-29.20291018	38.40241098	9734.04174805 TRW
0.00054169	0.02319336	-0.00381470	-0.00000000	-0.00000000	0.00188160	0.01342773 (RTCC-TRW)

VEL-MAG	FLT PATH	DELTA U	DELTA V	DELTA W	DELTA XDOT	DELTA YDOT	DELTA ZDOT
8524.1387	94.99036789	-995.	-8887.	0.01	0.00	0.00	2.30
8524.1409	94.98968887						
-0.00219727	0.00067902						

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA XDOT	DELTA YDOT	DELTA ZDOT
82.	-995.	-8887.	0.01	0.00	2.30

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
8943.	2.30

- Notes:
- The flight-path angle indicates the spacecraft is on the down-leg part of the ellipse.
 - Notice that the differences in declination and longitude has been decreasing for the last two comparisons.

12/21/67 APOLO RTCC COMPARISON
ASCC101 80MRS MS MANUAL, ACCEPT, NO UPD 1 EDIT 2 ITER VEH 1

TIME U.T. 9/11/67 18 HRS 6 MIN 18.000 SEC
TIME FROM LAUNCH C DAYS 6 HRS 6 MIN 17.000 SEC

X	Y	Z	XDOT	YDOT	ZDOT	
0.2221650E 01	-0.24346643E 01	-0.18784561E 01	0.87387007E 00	C.12142832E 01	-0.13962980E-01	PTCC
0.22218404E 01	-0.24347339E 01	-0.18781463E 01	0.87369514E 00	C.12144015E 01	-0.14322461E-01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (PTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	APOG PERIGEE	TRUE ANOM
50451643.00	0.59098269	30.30352521	55.17401457	71.79696274	187.11119507 PTCC
50451581.00	0.59098183	30.30106902	55.20575666	71.77079296	187.11068726 TRW
62.00	0.00000086	0.00245619	-0.03174210	0.002616978	0.00049782 (PTCC-TRW)

PERIOD	APOGEE	PERIGEE
316.29593658	9769.04077148	-45.13570947
316.29534912	9769.01745605	-45.13668823
0.00058746	0.02331543	-0.00302124

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
8696.4117	100.03203201	96.41511536	-29.67998457	40.06380653	9623.83044434 RTCC
8696.3961	100.03132915	96.42599023	-29.67460608	40.06225300	9623.82789086 TRW
0.01562500	0.00070286	-0.01447487	-0.00537848	0.00155354	0.00256348 (PTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
15.	-1021.	-7614.	0.00	0.02	2.42

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
7682.	2.42

- Notes:
- The differences in declination and longitude continue to decrease.
 - The X-and Y-angles get noisier as the slant range increases and the elevation decreases.

12/21/67 APOLLO RTCC COMPARISON
CROCO2 800RS MS MANUAL, ACCEPT, NO UPD IEDIT 21TER VEH 1

TIME U.T.
9/11/67 18 HRS 12 MIN 36.000 SEC

TIME FROM LAUNCH
0 DAYS 6 HRS 12 MIN 35.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
0.23088449E 01	-0.23023174E 01	-0.18761264E 01	0.78604912E 00	0.13060875E 01	0.58826740E-01	RTCC
0.23090165E 01	-0.23023772E 01	-0.18758446E 01	0.78586810E 00	0.13062077E 01	0.58456170E-01	TPW

DIFFERENCES IN OSCULATING ELEMENTS (PTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM	RTCC
50451622.00	0.59098405	30.30362177	55.17299032	71.79772663	189.46640396	RTCC
50451561.00	0.59098306	30.30097175	55.20465708	71.77166462	189.46587944	TPW
61.00	0.00000099	0.00265002	-0.03166676	0.02606201	0.00052452	(RTCC-TPW)

PERIOD	APNGEE	PERIGEE	DECLIN	LONG	HEIGHT	RTCC
316.29573059	9769.04650879	-45.15237427	-29.91591620	41.18466473	9514.13208008	RTCC
316.29515839	9769.02233887	-45.14828451	-29.91095328	41.18328142	9514.13696289	TPW
0.00057220	0.02416992	-0.00408936	-0.00496292	0.00138330	-0.00488281	(RTCC-TPW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT	RTCC
8867.3728	103.11888123	95.07251930	-29.91591620	41.18466473	9514.13208008	RTCC
8867.3463	103.11816216	95.08721828	-29.91095328	41.18328142	9514.13696289	TPW
0.02648926	0.00071907	-0.01465858	-0.00496292	0.00138330	-0.00488281	(RTCC-TPW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-30.	-1036.	-6538.	-0.00	0.03	2.50

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
7015.	2.50

Notes: • The differences in declination and longitude continue to decrease.

• The elevation of the CROCO3 data is now above 11 degrees, and the refraction problem becomes less significant.

12/21/67 APOLLO PTCC COMPARISON
ACNS103 800RS MS MANUAL, ACCEPT, NO UPD 2EDIT 2ITER VEH 1

TIME U.T. 9/11/67 18 HRS 20 MIN 24.000 SEC
TIME FROM LAUNCH
0 DAYS 6 HRS 20 MIN 23.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	PTCC
0.24035364E 01	-0.21253423E 01	-0.18624792E 01	0.66910802E 00	0.14159176E 01	0.15160973E 00	PTCC
0.24036813E 01	-0.21253860E 01	-0.18622500E 01	0.66891912E 00	0.14160390E 01	0.15122601E 00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	PERIGEE	APG PERIGEE	TRUE ANOM
50451632.00	0.59098478	30.20346465	55.17154264	71.79887390	192.44758797 RTCC
50451546.50	0.59098442	30.30088019	55.20323086	71.77280235	192.44703293 TRW
85.50	0.00000037	0.00258446	-0.03168821	0.02607155	0.00055504 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE
316.29582977	9769.05529785	-45.15783691
316.29502487	9769.02990723	-45.16055298
0.09080490	0.02539063	0.00271606

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
9145.5735	106.76282419	93.35308266	-30.13491917	42.66303873	9335.11267090 RTCC
9145.5270	106.76225281	93.36816502	-30.13079190	42.66191149	9335.12585449 TRW
0.04650879	0.00067139	-0.01508236	-0.00412726	0.00112724	-0.01318359 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-81.	-992.	-5661.	-0.00	0.05	2.58

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
5747.	2.58

Note: • The differences in declination and longitude continue to decrease.

12/21/67 APOLLO RTCC COMPARISON
ACNS106 720RS MS MANUAL, ACCEPT, NO UPD 2EDIT 2ITEP VEH 1

TIME U.T. TIME FROM LAUNCH
9/11/67 18 HRS 44 MIN 12.000 SEC 0 DAYS 6 HRS 44 MIN 11.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
0.25881538E 01	-0.15011513E 01	-0.17427365E 01	0.24184775E 00	0.17240886E 01	0.45953420E 00	RTCC
0.25882380E 01	-0.15011574E 01	-0.17426301E 01	0.24164082E 00	0.17242120E 01	0.45911492E 00	TPW

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50451751.50	0.59098724	30.30410671	55.16675091	71.80253124	202.27413750 RTCC
50451633.00	0.59098709	30.30084443	55.19828796	71.77668476	202.27345657 TRW
118.50	0.00000016	0.00326228	-0.03153706	0.02584648	0.00068092 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.29695511	9769.10717773	-45.17C16602	-30.21941614	48.06715250	8483.40710449 RTCC
316.29584122	9769.07470703	-45.17684937	-30.21726298	48.06644583	8483.44873047 TRW
0.00111389	0.03247070	0.00668335	-0.00215316	0.00070667	-0.04162598 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA W	DELTA VDOT	DELTA WDOT
10466.3291	116.30662060	87.62077522	-2685.	0.10	2.81
10466.2329	116.30608082	87.63652229	-2685.	0.10	2.81
0.09619141	0.00053978	-0.01574707	-2685.	0.10	2.81

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-252.	-886.	-2685.	-0.02	0.10	2.81

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
2842.	2.81

- Notes: • The differences in declination and longitude continue to decrease.
• This is the first comparison in the coast phase that could be considered good.

12/21/67 APOLLO RTCC COMPAPISON
 ASCC107 420RS MS MANUAL,ACCEPT,NO UPC IEDIT 21TER VEH 1

TIME U.T.
 9/11/67 18 HRS 54 MIN 36.000 SEC

TIME FROM LAUNCH
 0 DAYS 6 HRS 54 MIN 35.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
0.26105331E 01	-0.11917998E 01	-0.16501626E 01	0.10802160E-01	0.18435721E 01	0.61026240E 00	00	00
0.26105766E 01	-0.11917848E 01	-0.16501626E 01	0.10590856E-01	0.18435721E 01	0.60983597E 00	00	00

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50451935.50	0.59098665	30.30417848	55.16411495	71.80451584	207.11028099 RTCC
50451768.00	0.59098777	30.30099034	55.19574547	71.77857780	207.10952197 TRW
167.50	-0.00000112	0.00318813	-0.03163052	0.02593803	0.00075912 (PTCC-TRW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.29869080	9769.15039063	-45.15292358	-29.90048480	51.03569984	7959.29697500 RTCC
316.29711151	9769.11584473	-45.17352255	-29.89975214	51.03506804	7959.34545898 TRW
0.00157928	0.03454590	0.02059937	-0.00073266	0.00063181	0.04858398 (PTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-296.	-740.	-822.	-0.01	0.13	2.85

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
1145.	2.85

- Notes: ● The differences in declination and longitude continue to decrease, and the corresponding position differences have decreased.
- The heading angle has remained relatively constant over the last six comparisons.

12/21/67 APOLLO RTCC COMPARISON
CPOC108 800RS MS MANUAL, ACCEPT, NO UPD 2EDIT 2ITER VEH 1

TIME U.T.

9/11/67 18 HRS 58 MIN 24.000 SEC

TIME FROM LAUNCH

0 DAYS 6 HRS 58 MIN 23.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
0.26082512E 01	-0.10737411E 01	-0.16097696E 01	-0.825222670E-01	0.18839417E 01	0.66859005E 00	00	RTCC
0.26083198E 01	-0.10737333E 01	-0.16097033E 01	-0.82739289E-01	0.18840667E 01	0.66814366E 00	00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50451952.00	0.59098954	30.30554533	55.16385126	71.80442524	208.99649239 RTCC
50451856.50	0.59098770	30.30107832	55.19473886	71.77927494	208.99572754 TRW
95.50	0.00000184	0.00446701	-0.03088760	0.02515030	0.00076485 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	HEADING	DECLIN	LONG	HEIGHT
316.29883575	9769.1785887	-45.17578125	83.74929428	-29.71404743	52.24596500	7743.38049316 RTCC
316.29793930	9769.13818359	-45.16690063	83.76510429	-29.71250343	52.24528885	7743.44824219 TRW
0.00089645	0.04040527	-0.00888062	-0.01581001	-0.00154400	0.00067616	-0.06774902 (RTCC-TRW)

VEL-MAG	FLT PATH	DELTA U	DELTA V	DELTA W	DELTA XDOT	DELTA YDOT	DELTA ZDOT
11629.8541	120.66904354	-411.	-892.	-1744.	0.03	0.13	2.97
11629.7236	120.66847515						
0.13049316	0.00056839						

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA XDOT	DELTA YDOT	DELTA ZDOT
-411.	-892.	-1744.	0.03	0.13	2.97

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
2002.	2.97

Note: • DELTA WDOT remains the largest velocity component difference.

12/21/67 APOLO RTCC COMPARISON
CROC110 800BS MS MANUAL, ACCEPT, NO UPD IEDIT 2ITER VEH 1

TIME U.T.
9/11/67 19 HRS 25 MIN 36.000 SEC

TIME FROM LAUNCH
0 DAYS 7 HRS 25 MIN 35.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	PTCC	TRW
0.23887549E 01	-0.16620369E 00	0.12015590E 01	-0.95685932E 00	0.20865326E 01	0.11559039E 01	PTCC	
0.23887737E 01	-0.16625471E 00	-0.12016267E 01	-0.95706753E 00	0.20866428E 01	0.11554211E 01	TRW	

DIFFERENCES IN OSCULATING ELEMENTS (RTCC -- TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50451557.00	0.59099559	30.30858564	55.15699816	71.80734158	225.48091507 PTCC
50453477.50	0.59098983	30.30262705	55.18588448	71.78429604	225.47976303 TRW
79.50	0.00000577	0.00555856	-0.02888632	0.02304554	0.00115204 (RTCC-TRW)

PERIOD	APGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.31393433	9769.64929199	-45.11801147	-26.64712286	63.82093620	5785.30383301 PTCC
316.31317902	9769.58044434	-45.07550045	-26.64826918	63.81973410	5785.45556641 TRW
0.00075531	0.06884766	-0.04251095	0.00114632	0.00120211	-0.15173340 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA U	DELTA V	DELTA W
14939.1172	125.73710728	74.99734497	-922.	-724.	1355.
14938.8259	125.73651123	75.01249218			
0.29125977	0.00059605	-0.01514721			

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-922.	-724.	1355.	-0.14	0.26	3.11

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
1792.	3.12

Note: • DELTA WDOT remains the largest velocity component difference.

12/21/67 APOLLO RTCC COMPARISON
CPOC112 800RS MS MANUAL, ACCEPT, NO UPD IECIT 2ITER VEH 1

TIME U.T.
9/11/67 19 HRS 41 MIN 36.000 SEC

TIME FROM LAUNCH
0 DAYS 7 HRS 41 MIN 35.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
0.20340035E 01	0.38852659E 00	-0.84610811E 00	-0.17541411E 01	0.20371452E 01	0.15220216E 01	TRW
0.20340020E 01	0.38859899E 00	-0.84625245E 00	-0.17542578E 01	0.20372127E 01	0.15216226E 01	

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	APG PERIGEE	TRUE ANOM
50457442.50	0.59101762	30.21029224	55.15590334	71.80335331	239.65312004 RTCC
50457402.50	0.59100624	30.30503726	55.17889786	71.78541088	239.65172386 TRW
40.00	0.00001138	0.00525458	-0.02299452	0.01794243	0.00139618 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.35047531	9770.84936523	-45.03936768	-22.22464156	74.60735512	4262.64453125 RTCC
316.35009766	9770.74450684	-44.94757080	-22.22794676	74.60538101	4262.87091064 TRW
0.00037766	0.10485840	-0.09179688	0.00330520	0.00197411	-0.22637939 (PTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA U	DELTA V	DELTA W
17956.9509	126.02364922	68.84202576	-1376.	-419.	3058.
17956.4526	126.02299500	68.85345455	-1376.	-419.	3058.
0.49829102	0.00065422	-0.01142883	-1376.	-419.	3058.

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UTM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1376.	-419.	3058.	-0.33	0.38	2.40

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
3379.	2.45

Note: • Total position increased from the last comparison.

12/21/67 APOLLO RTCC COMPARISON
CPOC113 800RS MS MANUAL, ACCEPT, NO UPD IEDIT 3ITEP VEH 1

TIME U.T.
9/11/67 19 HRS 49 MIN 36.000 SEC

TIME FROM LAUNCH
0 DAYS 7 HRS 49 MIN 35.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
0.17655122E 01	0.65156433E 00	-0.62948190E 00	-0.22925636E 01	0.18869275E 01	0.17302087E 01	PTCC
0.17655172E 01	0.65163650E 00	-0.62963325E 00	-0.22925798E 01	0.18869647E 01	0.17299237E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50462396.00	0.59105257	30.31087112	55.15795803	71.79709911	249.26077271 RTCC
50462394.50	0.59103792	30.30707026	55.17503548	71.78399277	249.25926590 TRW
1.50	0.00001465	C.C0380087	-0.01707745	0.01310635	0.00150681 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	PTCC
316.39705658	9772.43676758	-44.59621582	TRW
316.39704514	9772.31469727	-44.87463379	(RTCC-TRW)
0.00001144	C.12207031	-0.12158203	

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
19975.7261	124.95620632	65.54886723	-18.49466157	82.04443455	3392.79684448 RTCC
19975.0747	124.95559025	65.55660439	-18.49853325	82.04242611	3393.05929565 TRW
0.65136719	0.00061607	-0.00773716	0.00387168	0.00200844	-0.26245117 (PTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1595.	-95.	3126.	-0.51	0.44	1.52

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
3510.	1.67

Note: • The first decrease in DELTA WDOT is noted in this comparison.

12/21/67 APOLLO RTCC COMPARISON
CPOC114 80RRS WS MANUAL, ACCEPT, NO LPC 2CITY 3ITP VEH 1

TIME U.T.
9/11/67 19 HRS 57 MIN 54.000 SEC

TIME FROM LAUNCH
0 DAYS 7 HRS 57 MIN 53.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	PTCC	TRW
0.14017767E 01	0.89158715E 00	0.37487219E 00	-0.20927252E 01	0.15387307E 01	0.19499501E 01	PTCC	
0.14018044E 01	0.89164056E 00	-0.37498491E 00	-0.20926352E 01	0.15387643E 01	0.19498084E 01	TRW	

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	PERIOD	APGEE	PERIGEE
50473324.50	0.59114037	30.31184435	316.49984741	9776.02758789	-44.58995572
50473481.00	0.59112588	30.30991840	316.50131989	9775.94836426	-44.55916138
-156.50	0.00001448	0.00192595	-0.00147247	0.07922363	-0.13079934

APG PERIGEE	TRUE ANOM
71.78712559	262.35582496 RTCC
71.77994537	262.35430145 TRW
0.00718021	0.00153351 (RTCC-TRW)

PERIOD	APGEE	PERIGEE	PTCC	TRW	(RTCC-TRW)
316.49984741	9776.02758789	-44.58995572	PTCC		
316.50131989	9775.94836426	-44.55916138	TRW		
-0.00147247	0.07922363	-0.13079934			(RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
22607.1819	122.45184898	62.25114536	-12.71584797	92.16416931	2423.92526245 RTCC
22606.4263	122.45150948	62.25470638	-12.71916187	92.16312790	2424.18551636 TRW
0.75561523	0.00033951	-0.00356102	0.00331390	0.00104141	-0.26025391 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1582.	400.	2118.	-0.73	0.43	0.54

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
2674.	1.01

Note: • Both flight-path angle and heading-angle differences decreased which accounts for the decrease in DELTA WDOT.

12/21/67 APOLLO RTCC COMPARISCA
 CR0C117 4508S MS MANUAL, ACCEPT, NO UPD 1EDIT 2ITER VEH 1

TIME U.T. 9/11/67 20 HRS 6 MIN 0. SEC
 TIME FROM LAUNCH
 C DAYS 8 HRS 5 MIN 59.000SEC
 X Y Z
 0.94290761E 00 0.10570214E 01 -0.99470480E-01
 C.94295493E 00 0.10570657E 01 -0.99553754E-01
 XDOT YDOT ZDOT
 0.82778556E 00 0.82778556E 00 0.21128349E 01
 0.82788765E 00 0.82788765E 00 0.21127647E 01

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)
 SEMI-MAJOR ECCEN INCL
 50495864.00 0.59135258 30.31400967
 50496036.50 0.59133878 30.31266928
 -172.50 0.00001381 C.C0134039

PERIOD APGEE PERIGEE
 316.71187210 9783.69384766 -45.23693848
 316.71350098 9783.62414551 -45.11059570
 -0.00162888 0.06970215 -0.12634277

VEL-MAG FLT PATH HEADING
 25859.5610 117.76988602 59.92819977
 25858.6733 117.76997948 59.92593875
 0.88769531 -0.00009346 -0.00173903

APG PERIGEE TRUE ANOM
 71.78102589 290.24121857 FTCC
 71.77641582 280.23918152 TRW
 0.00461006 0.00203705 (RTCC-TPW)

RTCC
 TRW
 (RTCC-TPW)

LONG HEIGHT
 105.94001865 1448.89797974 RTCC
 105.94025421 1449.13992310 TRW
 0.00023556 -0.24194336 (RTCC-TPW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)
 DELTA U DELTA V DELTA W
 -1470. 929. 1361.
 DELTA UDOT DELTA VDOT DELTA WDOT
 -1.09 0.43 0.14

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)
 DELTA POS DELTA VEL
 2208. 1.18

Note: • This is the last vector compared prior to SPS-2 burn.

12/27/67 APOLLO RTCC COMPARISON
 GWS118 260RS SS MANUAL ACCEPT, NO UPD SECIT 71TER VEH 1

TIME U.S.
 9/11/67 20 HRS 15 MIN 33.000 SEC
 TIME FROM LAUNCH
 0 DAYS 8 HRS 15 MIN 29.000 SEC

X	Y	Z	XDOT	YDOT	ZDOT
0.23395149E 00	0.10557817E 01	0.23581848E 00	-0.54703285E 01	-0.12384008E 01	-0.22203521E 01
0.23406398E 00	0.10557845E 01	0.23576354E 00	-0.54703876E 01	-0.12375022E 01	-0.22205444E 01

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL
0.94763604E 00	1.02217139	30.36519670
0.94817402E 09	1.02215964	30.36408353
0.53798400E 06	0.00001176	0.00111318

PERIOD

APGEE	PERIGEE
0.	16.54659707
0.	16.67538452
0.	-0.12838745

VEL-MAG

FLT PATH	HEADING
35063.7148	107.91010571
35063.3662	107.90788269
0.34863281	0.00222301

ASC PERIGEE

TRUE ANOM
35.41901398 RTCC
35.41482878 TRW
-0.00418520 (RTCC-TRW)

PTCC
 TRW
 (RTCC-TRW)

LONG

HEIGHT
373.40185547 RTCC
373.45205688 TRW
-0.05020142 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA XDOT	DELTA YDOT	DELTA ZDOT
-305.	2603.	31.	-5.15	1.30	0.68

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PVS	DELTA VEL
2621.	5.35

Note: • RTCC used doppler data in their fit. It was later discovered that the doppler data were extremely noisy and were not used to obtain the postflight entry trajectory. This accounts for the large total velocity difference.

12/18/67 APLLC RTCC COMPARISON
AGC VECTOR INSERTION

TIME U.T. TIME FROM LAUNCH
9/11/67 12 HRS 11 MIN 21.570 SEC C DAYS 0 HRS 11 MIN 20.570SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
-0.5470785E 00	0.67396173E 00	0.55229571E 00	-0.33605708E 01	-0.28367878E 01	0.13083260E 00	RTCC
-0.54669534E 00	0.67402440E 00	0.55306309E 00	-0.33587233E 01	-0.28362616E 01	0.13923372E 00	TRW

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
21537485.75	0.00044851	32.52295685	42.84311867	121.30057144	325.51454926 RTCC
21533161.75	0.00035589	32.57077312	43.02120829	343.45009613	103.19766617 TRW
4304.00	0.00009262	-0.04781628	-0.17808962	-222.14952469	222.31688309 (RTCC-TRW)

PERICD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
88.22123623	104.86211060	101.70251465			
88.19479370	103.84524536	101.32272339			
C.02644253	1.03686523	C.37975126			

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
25574.5530	90.01427746	37.57110939			
25565.6516	89.98109055	87.86077785			
8.70141602	0.03318691	0.11033154			

PERICD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
88.22123623	104.86211060	101.70251465			
88.19479370	103.84524536	101.32272339			
C.02644253	1.03686523	C.37975126			

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25565.6516	89.98109055	87.86077785			
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VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
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25565.6516	89.98109055	87.86077785			
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25574.5530	90.01427746	37.57110939			
25565.6516	89.98109055	87.86077785			
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25574.5530	90.01427746	37.57110939			
25565.6516	89.98109055	87.86077785			
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88.19479370	103.84524536	101.32272339			
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25574.5530	90.01427746	37.57110939			
25565.6516	89.98109055	87.86077785			
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88.22123623	104.86211060	101.70251465			
88.19479370	103.84524536	101.32272339			
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VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
25574.5530	90.01427746	37.57110939			
25565.6516	89.98109055	87.86077785			
8.70141602	0.03318691	0.11033154			

PERICD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
88.22123623	104.86211060	101.70251465			
88.19479370	103.84524536	101.32272339			
C.02644253	1.03686523	C.37975126			

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
25574.5530	90.01427746	37.57110939			
25565.6516	89.98109055	87.86077785			
8.70141602	0.03318691	0.11033154			

PERICD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
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12/18/67 APELLU RTCC CLMPARISON
IP KAW VECICR INSERTICN

TIME L.I. 9/11/67 12 HRS 11 MIN 22.250 SEC

TIME FROM LAUNCH
0 DAYS 0 HRS 11 MIN 21.250SEC

X	Y	Z	XDCI	YDOT	ZDOT	RTCC	TRW
-0.54715324E 00	0.67361501E 00	0.55309158E 00	-0.33565511E 01	-0.28396159E 01	0.13422298E 00	00	00
-0.54732901E 00	0.67348826E 00	0.55308922E 00	-0.33568377E 01	-0.28385863E 01	0.13732030E 00	00	00

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	PERIGEE	ARG PERIGEE	TRUE ANOM
21536326.00	0.03044851	32.57035072	101.51208496	167.22232437	279.50242996 RTCC
21533193.75	0.00035589	32.57076883	101.32470703	343.53779984	103.15633202 TRW
3134.25	0.00009262	-0.00071812	0.18737753	-176.31547546	176.34609795 (RTCC-TRW)

PERICD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
88.21412468	104.69152832	101.51208496	32.51028824	305.75674438	102.83465576 RTCC
88.15486904	103.84722500	101.32470703	32.50982245	305.74225616	102.85897827 TRW
0.01925564	0.84429532	0.18737753	0.00040579	0.01448822	-0.02432251 (RTCC-TRW)

VEL-MAG	FLI PATH	HEADING	DECLIN	LONG	HEIGHT
25567.8877	90.02574348	87.90987110	32.51028824	305.75674438	102.83465576 RTCC
25565.8518	89.98110008	87.89030933	32.50982245	305.74225616	102.85897827 TRW
2.03588867	0.04464340	0.01956177	0.00040579	0.01448822	-0.02432251 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-148.	-4584.	322.	-14.48	2.03	-12.20

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
4596.	19.05

Notes: • This is a better comparison than the AGC insertion vector.

• The heading angle, declination, and longitude are better determined than the AGC insertion vector. Only the flight-path angle has been degraded.

12/18/67 APCLL RTCC COMPARISON
LSE VECTOR INSERTION

TIME L.T.
9/11/67 12 HRS 11 MIN 22.250 SEC

TIME FROM LAUNCH
0 DAYS 0 HRS 11 MIN 21.250 SEC

X	Y	Z	XDCT	YDOT	ZDOT	RTCC	TRW
-0.54742449E 00	0.67351534E 00	0.55300654E 00	-0.33500906E 01	-0.28516366E 01	0.13688943E 00	00	00
-0.54732291E 00	0.67348626E 00	0.55308922E 00	-0.33568377E 01	-0.28385863E 01	0.13732030E 00	00	00

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NGDE	ANG PERIGEE	TRUE ANOM
21566431.50	0.00283008	32.57002449	43.19678920	146.01185608	300.53710938 RTCC
21533153.75	0.00035589	32.57076883	43.02108860	343.53779984	103.15633202 TRW
33237.75	0.00247419	-0.00074434	0.17570066	-197.52594376	157.38077736 (RTCC-TRW)

PERICD	APCGEE	PERIGEE	DECLIN	LUNG	HEIGHT
88.35514703	118.13115629	98.01116943	32.50367928	305.75674438	102.94412231 RTCC
88.15486904	103.84722500	101.32470703	32.50988245	305.76046753	102.85897827 TRW
C.20427755	14.25356725	-3.31353760	-0.00620317	-0.00372314	0.08514404 (RTCC-TRW)

VEL-MAG	FLI PATH	HEADING	DELTA U	DELTA V	DELTA W	DELTA WDGT
25584.9341	90.13511533	87.79793167	517.	1093.	-2374.	42.15
25565.8518	89.98110008	87.89030933				
19.08227535	C.15601525	-0.09237766				

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDGT
517.	1093.	-2374.	-71.85	18.97	42.15

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PLS	DELTA VEL
2664.	85.43

Note: • The position difference is small while the velocity difference is large. This could indicate that the RXY data were valid, and the doppler data were the reason for the bad velocity comparison.

12/18/67 APCLLC RTCC COMPARISON
IN VECTIL INSERTION

TIME L.I.
9/11/67 12 HRS 11 MIN 22.300 SEC

TIME FROM LAUNCH
0 DAYS 0 HRS 11 MIN 21.300SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
-0.54655705E 00	0.67416227E 00	0.55288052E 00	-0.33589212E 01	-0.28365588E 01	0.13792717E 00	00	00
-0.54732981E 00	0.67348626E 00	0.55308922E 00	-0.33568377E 01	-0.28385863E 01	0.13732030E 00	00	00

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NGDE	ARG PERIGEE	TRUE ANOM
21532747.25	0.00012207	32.56121111	42.99603115	199.76003838	246.89731216 RTCC
21533193.75	0.00035589	32.57076883	43.02108860	343.53779984	103.15633202 TRW
-446.50	-0.00023382	-0.00955772	-0.02445745	-143.77776146	143.74098015 (RTCC-TRW)

PERIOD	APGEE	PERIGEE	HEADING	DECLIN	LONG	HEIGHT
88.15212437	102.94505888	102.07992554	37.86766815	32.49898529	305.75674438	102.57925415 RTCC
88.15486904	103.84722500	101.32470703	87.89030933	32.50988245	305.68912506	102.85897827 TRW
-0.00274467	-0.90213013	0.75521851	-0.02264118	-0.01059710	0.06761932	-0.27972412 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN LVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1711.	-21571.	-3297.	16.05	1.74	-6.11

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA PCS	DELTA VEL
21886.	17.26

Notes: • The velocity comparison is the best of the four special insertion vectors.

• The largest position component difference is DELTA V.

12/15/67 APOLLO RTCC COMPARISCA
RD00025 VECTOR USED TO BUILD AGC NAVIGATION UPDATE PRIOR TO J2

TIME U.T.
9/11/67 13 HRS 39 MIN 24.000 SEC

TIME FROM LAUNCH
0 DAYS 1 HRS 39 MIN 23.000SEC

X	Y	Z	VDOT	VDOT	VDOT	7DDT	PTCC	TPW
-0.5371331CE 00	0.69316678E 00	0.55353022E 00	0.33928438E 01	0.27910329E 01	0.15246080E 00	00	PTCC	
-0.53706826E 00	0.68319878E 00	0.55353398E 00	0.33927091E 01	0.27910152E 01	0.15259085E 00	00	TPW	

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TPW)

SEMI-MAJOR	ECCEN	INCL	NODE	APG PERIGEE	TRUE ANOM
21562613.50	0.00012207	32.57087326	42.55559587	77.10067081	9.20631886 PTCC
21561086.00	-0.	32.57178211	42.55916595	155.07208824	291.22798920 TPW
1527.50	0.00012207	-0.00090885	0.00357008	77.97141743	282.02166748 (RTCC-TPW)

PERIOD	APGEE	PERIGEE
88.37567520	107.96105347	106.99465942
88.36628246	107.17648315	107.17648315
0.00939274	0.68457031	-0.18182373

VEL-MAG	FLY PATH	HEADING	DECLIN	LONG	HEIGHT
25552.4407	89.9924946	87.64282744	32.49490261	282.76034927	107.14071655 PTCC
25551.7976	90.00300694	87.63934517	32.49552393	282.76501083	107.10430908 TPW
0.64306641	-0.00375748	0.00448227	0.00062132	0.00456156	0.03640747 (PTCC-TPW)

DIFFERENCE BETWEEN PTCC AND TPW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
221.	1470.	-295.	0.07	0.64	-0.98

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
1515.	1.09

Note: ● This vector had to be propagated more than an hour using a simple vent model. Therefore, it might be better to use a vector that is not as good, e.g. CROCO2, but one which would require less propagation.

12/15/67 APOLLO RTCC COMPARISON
WHSC047 REST RTCC VECTOR PRINT TO TLI

TIME U.T.
9/11/67 15 HRS 5 MIN 18.000 SEC

TIME FROM LAUNCH
0 DAYS 3 HRS 5 MIN 17.000SEC

X	Y	Z	YDOT	YDDOT	ZDOT	RTCC
-0.39326445E 00	0.78502361E 00	0.54054213E 00	0.37395138E 01	0.22442219E 01	0.53895558E 00	RTCC
-0.39318620E 00	0.78503295E 00	0.54049316E 00	0.37395294E 01	0.22442317E 01	0.53892444E 00	TRW

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
21577562.00	0.00014950	32.57505131	42.12195110	49.76107693	27.07392985 RTCC
21575705.25	-0.	32.57406855	42.12173605	123.57276535	313.25813293 TRW
1856.75	0.00014950	0.00098276	0.00021505	-73.81168842	286.18419266 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	HEADING	DECLIN	LONG	HEIGHT
88.46759129	110.41897583	105.35711670	81.72064590	31.61801744	249.65951157	109.61373901 RTCC
88.45617199	109.58248901	105.58248501	81.71844578	31.61647773	249.66435051	109.44702148 TRW
0.01141930	0.82648682	-0.22537231	0.00220013	0.00153971	0.00483894	0.16671753 (RTCC-TRW)

VEL-MAG	FLT PATH	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
25543.4941	89.99773788	1619.	350.	0.13	0.10	0.15
25543.5947	90.00232506	-0.00458717	0.00220013	0.00153971	0.00483894	0.16671753 (RTCC-TRW)
-0.10058594	-0.00458717	-0.00458717	0.00220013	0.00153971	0.00483894	0.16671753 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
1013.	1619.	350.	0.13	0.10	0.15

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
1942.	0.22

Note: • This is a good vector comparison.

12/18/67 APOLLO RTCC COMPARISON
 ARG HIGH SPEED CUTOFF VECTOR FOLLOWING TLI

TIME U.T. TIME FROM LAUNCH
 9/11/67 15 HRS 16 MIN 45.700 SEC 0 DAYS 3 HRS 16 MIN 44.700SEC

X	Y	Z	XDOT	YDOT	ZDOT	PTCC	TRW
-0.95644128E 00	0.13827205E 00	0.50569079E 00	-0.24582053E 01	-0.46782792E 01	-0.37702588E 00	PTCC	
-0.95707791E 00	0.13625859E 00	0.50498237E 00	-0.24518507E 01	-0.46748206E 01	-0.37973752E 00	TRW	

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
49383292.00	0.58139218	30.31579065	55.27220392	71.32795811	41.96070719 PTCC
49021443.50	0.57879791	30.30291748	55.25339222	71.15443325	42.26643133 TRW
361848.50	0.00259426	0.01287317	0.01881170	0.17352486	-0.30572414 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	RTCC	TRW
306.30260849	9411.35498047	-39.11001587	RTCC	
302.94220352	9296.24890137	-43.10900879	TRW	
3.36040497	115.10607910	3.59899292	(RTCC-TRW)	

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
30797.0352	74.81576920	103.01685905	27.62221336	302.07939911	314.96978760 RTCC
30763.2822	74.75443459	103.07769394	27.58085656	301.95589447	314.88998413 TRW
33.75292969	0.06133461	-0.06083488	0.04135680	0.12350464	0.07980347 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
437.	-46192.	6205.	37.20	24.83	4.08

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
46609.	44.91

Note: • A very large difference is observed in the semimajor axis which is reflected in the predicted apogee difference.

12/18/67 APOLLO RTCC COMPARISON
IP RAW HIGH SPEED CUTOFF VECTOR FOLLOWING TLI

TIME U.T. 9/11/67 15 HRS 18 MIN 8.700 SEC
TIME FROM LAUNCH 0 DAYS 3 HRS 18 MIN 7.700SEC
X Y Z XDOT YDOT ZDOT
-0.10096085E 01 0.28470740E-01 0.45433374E 00 -0.21212768E 01 -0.47025678E 01 -0.54783587E 00 RTCC
-0.10097472E 01 0.28079126E-01 0.49423577E 00 -0.21191704E 01 -0.47029126E 01 -0.54929841E 00 TPW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TPW)

SEMI-MAJOR	ECCEN	INCL	NODE	APG PERIGEE	TRUE ANOM
49034937.50	0.57895979	30.30476455	55.25201178	71.13082790	49.27109480 RTCC
49024371.50	0.57880835	30.30487776	55.24556351	71.16830730	48.26057005 TRW
10566.00	0.00015143	-0.00011277	0.00644827	0.03747940	0.01052475 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
303.06729889	9301.06164551	-43.479584C	26.07872415	308.24245453	431.35922241 RTCC
302.96934128	9297.09399414	-42.59020386	26.07138181	308.22003174	431.60574341 TRW
0.09795761	3.96765137	-0.48965454	0.00734234	0.02242279	-0.24652100 (RTCC-TPW)

VEL-MAG	FLT PATH	HEADING	DELTA U	DELTA V	DELTA W
30155.6074	72.67784882	106.00952485	14.78	-8783.	616.
30153.3184	72.68452454	106.02267265	0.00734234	-2.21	1.69
2.28906250	-0.00667572	-0.01274776	0.00734234	0.02242279	-0.24652100 (RTCC-TPW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT, FT/SEC)
DELTA U -1500.
DELTA V -8783.
DELTA W 616.

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)
DELTA POS 8932.
DELTA VEL 15.04

Note: • This vector produced a better comparison than the AGC vector.

12/18/67 APOLLO RTCC COMPARISON
ANTC059 BEST RTCC VECTOR PRIOR TO SPS-1

TIME U.T. 9/11/67 15 HRS 22 MIN 18.000 SEC
TIME FROM LAUNCH
0 DAYS 3 HRS 22 MIN 17.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC	TRW
-0.11245284E 01	-0.29535883E 00	0.44153729E 00	-0.12228340E 01	-0.45970410E 01	-0.94554396E 00	00	RTCC
-0.11244355E 01	-0.29531048E 00	0.44152647E 00	-0.12221895E 01	-0.45971460E 01	-0.94570591E 00	00	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
49045100.00	0.57895759	30.311409CC	55.22689009	71.19280529	64.10400009 RTCC
49028595.50	0.57878703	30.31067657	55.23028231	71.20217514	64.09025383 TRW
16504.50	0.00017056	0.00073242	-0.00339222	-0.00936985	0.01374626 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
303.16151428	9303.68457031	-42.75793457	20.79485273	323.50901031	841.85177612 RTCC
303.00849915	9298.01953125	-42.52536C11	20.79605699	323.51015091	841.50985718 TRW
0.15301514	5.66503906	-0.23257446	-0.00120425	-0.00114059	0.34191895 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA UDOT	DELTA VDOT
28191.4163	67.42686367	112.56408882	3.58	-1.29
28191.2346	67.43602943	112.56195831		
0.18164063	-0.00916576	0.00213051		

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
2077.	658.	-319.	3.58	-1.29	-0.92

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
2202.	3.91

Note: • DELTA U and DELTA UDOT are the largest component differences and probably reflect the pass geometry of the station; i. e., the station is not far off the track of the vehicle, and the vehicle is moving up and away from the station.

12/21/67 APOLLO RTCC COMPARISON
IP RAW HIGH SPEED CUTCFF VECTOR FOLLOWING SPS-1

TIME U.T.

9/11/67 15 HRS 29 MIN 53.800 SEC

TIME FROM LAUNCH
0 DAYS 3 HRS 29 MIN 52.800SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
-0.119941C5E 01	-0.84521560E 00	0.29424216E 00	-0.73265870E-01	-0.40742976E 01	-0.13227040E 01	RTCC
-0.11956878E 01	-0.8456744CE 00	0.29384857E 00	-0.72350549E-01	-0.40732005E 01	-0.13236734E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	PERIGEE	TRUE ANOM
50481705.50	0.59138160	30.30673885	71.74830055	85.32028770 RTCC
50485590.00	0.59130117	30.30642255	71.78301811	85.32425785 TRW
-3884.50	0.00008043	0.00031590	-0.03471756	-0.00397015 (RTCC-TRW)

PERIGD	APGEE	PERIGEE	RTCC
316.57868576	9780.22668457	-46.43029785	TRW
316.61522293	9780.57580566	-45.50076294	(RTCC-TRW)
-0.03653717	-0.34512109	-0.92953491	

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
24903.0920	60.65177631	118.29437447	11.33926499	342.06984329	1712.57974243 RTCC
24898.6780	60.65386C57	118.30089760	11.32081699	342.06156540	1713.96340942 TRW
4.41406250	-0.00208426	-0.00652313	C.01844800	0.00827789	-1.38366699 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-8409.	-8686.	6775.	8.97	0.02	4.50

MAGNITUDE OF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA POS	DELTA VEL
13859.	10.04

Note: • Large differences in total position and total velocity should be noted.

12/21/67 APCLLC RTCC COMPARISON
ACNS079 VECTOR USED TO BUILD AGC NAVIGATION UPDATE PRIOR TO SPS-2

TIME U.T. 9/11/67 16 HRS 16 MIN 36.000 SEC
TIME FROM LAUNCH
0 DAYS 4 HRS 16 MIN 35.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
-0.30307608E 00	-0.27581417E 01	-0.77383221E 00	0.16131143E 01	-0.12450710E 01	-0.11887717E 01	RTCC
-0.30374835E 00	-0.27581738E 01	-0.77410777E 00	0.16123398E 01	-0.12453520E 01	-0.11892609E 01	TRW

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50453722.50	0.59C87409	30.28983331	55.21042347	71.78972435	140.39202309 RTCC
50454994.00	0.59097314	30.30585654	55.20678234	71.77684975	140.39828110 TRW
-1271.50	-0.00C09905	-0.01602364	0.00364113	0.01287460	-0.00625801 (RTCC-TRW)

PERIOD	APCGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.31549C72	9768.68359375	-44.05796143	-15.58294904	18.89710498	6479.36901855 RTCC
316.32744217	9769.83898926	-44.83480835	-15.58766472	18.91083026	6479.97375488 TRW
-0.01195145	-1.15539551	0.73684652	0.00471568	-0.01372528	-0.60473633 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
13712.9552	55.33699560	116.30655384	-3676.	10268.	10614.	-2.80	2.89	3.85
13712.1732	55.33026075	116.32282543						
0.78198242	0.00673485	-0.01627159						

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVW COORDINATES (FT,FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-3676.	10268.	10614.	-2.80	2.89	3.85

MAGNITUDE CF VECTOR DIFFERENCE (FT,FT/SEC)

DELTA PCS	DELTA VEL
15219.	5.57

Note: ● Two reasons for the bad comparison are

- 1) Since there were no Carnarvon data in the RTCC fit, it was, in essence, a single station fit.
- 2) The RTCC used the bad Ascension data segment.

12/21/67 APOLLO RTCC COMPARISON
CROC117 BEST RTCC VECTOR PRIOR TO SPS-2

TIME U.T.
9/11/67 20 HRS 6 MIN 0. SEC

TIME FROM LAUNCH
0 DAYS 8 HRS 5 MIN 59.000SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
0.94290761E 00	0.10570214E 01	-0.95470480E-01	-0.38265547E 01	0.82778556E 00	0.21128349E 01	RTCC
0.94295493E 00	0.10570657E 01	-0.95553754E-01	-0.38263937E 01	0.82788765E 00	0.21127647E 01	TRW

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	NODE	ARG PERIGEE	TRUE ANOM
50495864.00	0.59135258	30.21400567	55.16399813	71.78102589	280.24121857 RTCC
50496036.50	0.59133878	30.21266928	55.16962242	71.77641582	280.23918152 TRW
-172.50	0.00001381	0.00134039	-0.00562429	0.00461006	0.00203705 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
316.71187210	9783.69384766	-45.23653848	-4.01697439	105.94001865	1448.89797974 RTCC
316.71350098	9783.62414551	-45.11059570	-4.02014363	105.94025421	1449.13992310 TRW
-0.00162888	0.06970215	-0.12634277	0.00316924	-0.00023556	-0.24194336 (RTCC-TRW)

VEL-MAG	FLT PATH	HEADING	DELTA U	DELTA V	DELTA W
25859.5610	117.76988602	59.52819977	-1470.	929.	1361.
25858.6733	117.76997948	59.52953879			
0.88769531	-0.00009346	-0.00173903			

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVM COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-1470.	929.	1361.	-1.09	0.43	0.14

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
2208.	1.18

Note: • This is a good vector comparison.

12/27/67 APOLLO RTCC COMPARISON
AGC HIGH SPEED CUTOFF VECTOR FOLLOWING SPS-2

TIME U.T.
9/11/67 20 HRS 15 MIN 44.320 SEC

TIME FROM LAUNCH
0 DAYS 8 HRS 15 MIN 43.320SEC

X	Y	Z	XDOT	YDOT	ZDOT	RTCC
0.21074693E 00	0.10504419E 01	0.24957306E 00	-0.54857817E 01	-0.13085891E 01	0.21931802E 01	PTCC
0.21227647E 00	0.10507387E 01	0.24856836E 00	-0.54835346E 01	-0.12995575E 01	0.22061191E 01	TRW

DIFFERENCES IN OSCILLATING ELEMENTS (RTCC - TRW)

SEMI-MAJOR	ECCEN	INCL	PERIGEE	TRUE ANOM
0.99374430E 09	1.02112928	30.29166460	55.15390539	-34.29955387 PTCC
0.94800990E 09	1.02216330	30.36378121	55.26236563	-34.22729547 TRW
0.45734408E 09	-0.00103402	-0.07211661	-0.10846424	-0.07225847 (RTCC-TRW)

PERIOD	APOGEE	PERIGEE
0.	0.	14.35659790
0.	0.	16.64874268
0.	0.	-2.29214478

VEL-MAG	FLT PATH	HEADING	DECLIN	LONG	HEIGHT
35173.4658	107.33461761	62.44749737	13.11305785	133.81172562	347.20782471 PTCC
35177.6533	107.30700111	62.34104109	13.05506110	133.88975961	348.41247559 TRW
-4.18750000	0.02761650	0.10645628	0.05799675	-0.07703400	-1.20465088 (RTCC-TRW)

DIFFERENCE BETWEEN RTCC AND TRW VECTORS IN UVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA XDOT	DELTA YDOT	DELTA ZDOT
-7351.	37517.	6650.	-69.63	-26.21	-55.20

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
38805.	92.64

Note: • This vector comparison is worse than the AGC high speed cutoff vector following TLI, although the second S-IVB burn was larger than the SPS-2 burn.

12/27/67 APOLLO RTCC COMPATISCA
GWMS HIGH SPEED CUTOFF VECTOR FOLLOWING SPS-2

TIME U.T.

9/11/67 20 HPS 16 MIN 29.500 SEC

TIME FROM LAUNCH
0 DAYS 8 HPS 16 MIN 27.500SEC

X	Y	Z	YDOT	YDOT	YDOT	PTCC	TRW
0.14466596E 00	0.10335412E 01	0.27541042E 00	-0.55190181E 01	-0.14915747E 01	0.21522257E 01	PTCC	
0.14476399E 00	0.10335896E 01	0.27534537E 00	-0.55172277E 01	-0.14965887E 01	0.21564272E 01	TRW	

DIFFERENCES IN OSCULATING ELEMENTS (RTCC - TPW)

SEMI-MAJOR	ECCEN	INCL	NODE	APC PERIGEE	TRUE ANOM
0.98078578E 09	1.02142830	30.21510592	55.20247984	60.77006817	30.40413404 RTCC
0.94777618E 09	1.02216825	30.36274981	55.26126289	60.77573919	30.46669984 TRW
0.33009600E 08	-0.00073995	-0.04764390	-0.05878305	-0.00567102	0.06256580 (RTCC-TPW)

PERIOD	APOGEE	PERIGEE	DECLIN	LONG	HEIGHT
0.	0.	17.56124878	14.78332090	137.07569122	275.87203979 RTCC
0.	0.	16.56793213	14.77914846	137.08065033	276.01989746 TRW
0.	0.	0.99331665	0.00417244	-0.00495011	-0.14785767 (RTCC-TPW)

VEL-MAG	FLT PATH	HEADING	DELTA W	DELTA UDOT	DELTA VDOT
35508.1729	105.36710930	63.22536583	614.	20.28	1.01
35514.5127	105.40439701	63.17198277			
-6.33984375	-0.03728771	0.05738306			

DIFFERENCE BETWEEN RTCC AND TPW VECTORS IN LVA COORDINATES (FT, FT/SEC)

DELTA U	DELTA V	DELTA W	DELTA UDOT	DELTA VDOT	DELTA WDOT
-899.	2429.	614.	20.28	1.01	33.79

MAGNITUDE OF VECTOR DIFFERENCE (FT, FT/SEC)

DELTA POS	DELTA VEL
2662.	39.42

Note: • The position difference is reasonable, but the velocity difference is large. It was noticed that the low speed doppler was very noisy, and it was deleted from the postflight fit.